THE NATIONAL NANOTECHNOLOGY INITIATIVE AMENDMENTS ACT OF 2008

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

APRIL 16, 2008

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THE NATIONAL NANOTECHNOLOGY INITIATIVE AMENDMENTS ACT OF 2008

WEDNESDAY, APRIL 16, 2008

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Committee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Bart Gordon [Chairman of the Committee] presiding.

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The National Nanotechnology Initiative Amendments Act of 2008

WEDNESDAY, APRIL 16, 2008
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Wednesday, April 16, 2008, the Committee on Science and Technology will hold a hearing to review legislation that proposes changes to various aspects of the planning and implementation mechanisms for and to the content of the National Nanotechnology Initiative (NNI). The legislation includes changes to strengthen the planning and implementation of the environment, health, & safety (EHS) component of NNI; to increase emphasis on nanomanufacturing research, technology transfer, and commercialization of research results flowing from the program; to create a new NNI component of focused, large-scale research and development projects in areas of national importance; and to enhance support for K–16 nanotechnology-related education programs.

The legislation is based on findings and recommendations from formal reviews in 2002 and 2006 of the NNI by the National Academy of Sciences and in 2005 by the President's Council of Advisors for Science and Technology, which currently serves as the advisory committee for the NNI; witness testimony from NNI hearings from this and the past Congress; and recommendations resulting from staff discussions with various stakeholder groups.

A section-by-section summary of the bill is attached as an appendix to this memo.

2. Witnesses

Mr. Floyd E. Kvamme, Co-Chair, President's Council of Advisors on Science and Technology

Mr. Sean Murdock, Executive Director, NanoBusiness Alliance

Dr. Joseph Krajcik, Associate Dean for Research and Professor of Education, University of Michigan

Dr. Andrew Maynard, Chief Science Advisor, Project on Emerging Nanotechnologies, Woodrow Wilson Center

Dr. Raymond David, Manager of Toxicology, BASF Corporation on behalf of the American Chemistry Council

Dr. Robert R. Doering, Senior Fellow and Research Strategy Manager, Texas Instruments and on behalf of the Semiconductor Industry Association.

3. Overarching Questions

- Does the legislation address key issues for improving the way the NNI is planned and implemented and for ensuring that the program is positioned to help maintain U.S. leadership in nanotechnology?
- Are the changes proposed in the legislation to strengthen the planning, coordination, and prioritization process for research to address concerns about environmental and safety ramifications of nanotechnology likely to be effective? Is the requirement for a minimum funding level for this aspect of the program reasonable and necessary?
- Will the bill assist in overcoming the barriers to commercialization of nanotechnologies, help enhance NNI support for research in areas relevant to the needs of industry, and make user facilities supported under the NNI more welcoming to industrial users, thereby assisting with the transfer of research results to usable products that benefit the public?

- Is there a need for resources under the NNI to be readjusted to include a component for support of large-scale research and development projects focused on specific problems of national importance?
- Does the proposed legislation adequately address support for nanotechnology education under the NNI?

4. Background

Summary of Past NNI Hearings

During the 110th Congress, the Committee has held three NNI related hearings. The first, *Nanotechnology Education* [Serial No. 110–60], was held October 2nd, 2007 by the Subcommittee on Research and Science Education. The witnesses, who represented the Federal Government, industry, and educational institutions and science educators at all levels, agreed that nanotechnology education is an important component of a strategy to capitalize on the promise of this advancing field. Several witnesses discussed the importance of early nanotechnology education, including informal education, for generating awareness, information and excitement about nanotechnology among young students and the general public. Witnesses were unanimous in expressing support for increasing formal education in nanotechnology beginning at the undergraduate level, including at two-year colleges because of their important role in supplying much of the 21st Century skilled workforce. A representative from the National Science Foundation provided an overview of the many activities in formal and informal nanotechnology education at all levels already supported by the Federal Government.

A second hearing, *Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation under the National Nanotechnology Initiative* [Serial No. 110–69], was held on October 31, 2007. This hearing addressed the need and motivation for research on the environmental, health and safety (EHS) aspects of nanotechnology. In addition, the hearing sought to determine the current state of planning and implementation of EHS research under the National Nanotechnology Initiative (NNI), and explore whether changes are needed to the current mechanisms for planning and implementing EHS research. Witnesses included the representatives from the organizations charged with the development of the EHS plan as well as non-governmental organizations focused on the societal implications of nanotechnology. The hearing highlighted the unanimous position by all witnesses regarding the importance of EHS research for the development of nanotechnology and the necessity of a well designed and adequately funded EHS research component of the NNI. However, there was concern that the interagency planning for and implementation of the EHS research component of NNI was not moving with the urgency it deserved. While the organizations responsible for plan development and implementation claimed that the current process is effective and that the participating agencies believe the process is working well, the non-governmental organizations were unanimous in their recommendations for changes in the planning process as well as increases in the priority of EHS in the overall NNI basic research funding.

A third hearing, *The Transfer of National Nanotechnology Initiative Research Outcomes for Commercial and Public Benefit* [Serial No. 110–82] was held on March 11, 2008 by the Subcommittee on Research and Science Education. Witnesses included representatives of State- and federally-funded nanotechnology research and user facilities, industry, and a state-based technology transfer and funding organization. The witnesses stressed the importance of basic research in nanomanufacturing and adequate funding of geographically diverse user facilities. The witnesses were clear that basic research funding should be broad to allow for new discoveries and pioneering research; however, they indicated that it would be wise to focus some funding and planning toward commercialization. They suggested that this might be accomplished through demonstration projects or by defining areas of global competitiveness. Many of the witnesses testified that the SBIR and ATP/TIP programs are very important for the development of innovative technologies and felt that the program should emphasize the funding of nanotechnology projects.

NNI Organization and Funding

The National Nanotechnology Initiative was authorized by the *21st Century Nanotechnology Research and Development Act of 2003* (P.L. 108–153). In accordance with the Act, the National Science and Technology Council (NSTC) through the Nanoscale Science, Engineering, and Technology (NSET) Subcommittee plans and coordinates the NNI. The Act authorized the National Nanotechnology Coordination Office (NNCO) to provide technical and administrative support to the NSET for this coordination. There are currently twenty-six federal agencies that participate in the

National Nanotechnology Initiative, with 13 of those agencies reporting a research and development budget. Research related to the NNI is organized into eight program component areas including: Fundamental Nanoscale Phenomena and Processes; Nanomaterials; Nanoscale Devices and Systems; Instrumentation Research, Metrology, and Standards; Nanomanufacturing; Major Research Facilities and Instrument Acquisition; Environment, Health, and Safety; and Education and Societal Dimensions. More information on the organization and structure of the NNI can be found in the Congressional Research Service Report, *The National Nanotechnology Initiative: Overview, Reauthorization, and Appropriations Issues* at *http://www.congress.gov/erp/rl/pdf/RL34401.pdf.*

The total estimated NNI budget for FY 2008 was $1.49 billion. Total planned funding for the NNI in FY 2009 is $1.53 billion. More information on the NNI program content and budget can be found at *http://www.nano.gov/NNI_FY09_budget_summary.pdf* and *http://www.nano.gov/NNI_08Budget.pdf.*

Planned 2009 Agency Investment by Program Component Area[1]

Dollars in millions
(% change from 2008 Estimates, if any)

	Fundamental Phenomena & Processes	Nanomaterials	Nanoscale Devices & Systems	Instrument Research, Metrology & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, & Safety	Education & Societal Dimensions	NNI Total
DOD	227.8 (-12%)	55.2 (-20%)	107.7 (-10%)	3.6 (-55%)	12.8 (137%)	22.1 (-10%)	1.8 (-10%)		**431.0**
NSF	141.7 (2 %)	62.5 (0.6%)	51.6 (3%)	16.0	26.9	32.1 (2%)	30.6 (5%)	35.5 (5%)	**396.9**
DOE	96.9 (89%)	63.5 (-18%)	8.1 (-38%)	32.0 (167%)	6.0 (200%)	101.2 (10%)	3.0	0.5	**311.2**
DHHS (NIH)	55.5 (-0.2%)	25.4	125.8	5.9	0.8		7.7	4.6	**225.7**
DOC (NIST)	24.5 (9%)	8.5 (15%)	22.7 (5%)	20.9 (30%)	15.3 (6%)	5.7 (-2%)	12.8 (1500%)		**110.4**
NASA	1.2 (-20%)	9.8 (1%)	7.7 (24%)			0.2 (-50%)	0.1 (-50%)		**19.0**
EPA	0.2	0.2	0.2				14.3 (49%)		**14.9**
DHHS (NIOSH)							6.0		**6.0**
USDA (FS)	1.7 (31%)	1.3 (-32%)	0.7 (-42%)	1.1 (175%)	0.2				**5.0**
USDA (CREES)	0.4 (-43%)	0.8 (-50%)	1.5 (-52%)		0.1 (-80%)		0.1	0.1	**3.0**
DOJ				2.0					**2.0**
DHS			1.0						**1.0**
DOT (FHWA)	0.9								**0.9**
TOTAL	**550.8 (4%)**	**227.2 (-11%)**	**327.0 (-5%)**	**81.5 (35%)**	**62.1 (24%)**	**161.3 (5%)**	**76.4 (30%)**	**40.7 (4%)**	**1527.0 (2%)**

[1] Adapted from the *Summary of the FY2009 National Nanotechnology Initiative Budget*, February 2008. Available at http://www.nano.gov/.

Spending on EHS, Nanomanufacturing, and Education

EHS: The President's FY 2009 budget requests $1.5 billion for the NNI. Of this amount, the budget proposes $76.4 million (five percent of the overall program) for research on EHS research. This is a 30 percent increase over the FY08 funding level. More than 40 percent of this funding would go to NSF.

Nanomanufacturing and Commercialization: The FY 2008 estimated budget for nanomanufacturing research (a component that is closely tied to bridging the gap between basic research and the development of commercial products) was $50.2 mil-

lion dollars which is 3.3 percent of the total budget. The NNI planned investment in nanomanufacturing research for FY 2009 is $62.1 million, a 24 percent increase. This amount is four percent of the total FY 2009 proposed budget. In addition, $161.3 million is planned for major facilities and instrument acquisition, which can be utilized towards production of prototypes leading to commercialization.

Education: As part of its contribution to the NNI, NSF supports a number of educational activities designed to teach K–16 students, science teachers, faculty members, and the general public about nanotechnology. Major education programs include the National Center for Learning and Teaching (NCLT) in Nanoscale Science and Engineering and the Nanoscale Informal Science Education (NISE) Network. NCLT is a consortium of five universities with a mission to foster the Nation's talent in nanoscale science and engineering (NSSE) by developing methods for learning and teaching through inquiry and design of nanoscale materials and applications. They perform research and serve as a clearinghouse for information regarding NSSE curriculum, teaching methodologies, and professional development for the undergraduate and K–12 levels. NCLT is operating in the last year of a five-year $15,000,000 million grant. The NISE network received a $12.4 million dollar grant from NSF in 2005 to develop methods of introducing the nanotechnology to the public and to draw students to careers in NSSE.

NSF also has a Nanotechnology Undergraduate Education Program funded at $42.7 million since 2003. The grants in this program have gone to develop curriculum and purchase equipment for undergraduate students in different science and engineering disciplines. As part of the Advanced Technology Education Centers program, NSF has provided $2.68 million since 2004 to develop nanotechnology related technician education programs at community colleges.

Environment, Health, & Safety Planning

In October 2003, the NSET organized an interagency Nanotechnology Environmental and Health Implications (NEHI) Working Group to coordinate environmental and safety research carried out under the NNI. One of the NEHI Working Group's initial tasks was developing a prioritized plan for EHS research. In March 2006, the Administration informed the Science Committee that this report would be completed that spring, but the document that was finally released in September 2006 was a non-prioritized list of EHS research areas. A further iteration of the EHS research plan, which was released for public comment in August 2007, presented a rationale for the process of defining EHS research priorities and provided a reduced set of priorities based on the previous report. Finally, in February 2008, the *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research*[2] document was released. This document provided a more in depth assessment of current research needs and priorities; however, it failed to provide a schedule and timelines for meeting objectives and the proposed funding levels by topic and by agency.

Commercialization and Technology Transfer of Nanotechnology

User Facilities

The NNI funding agencies support nanotechnology user facilities to assist researchers (academic, government, and industry) in fabricating and studying nanoscale materials and devices. The facilities may also be used by companies for developing ideas into prototypes and investigating proof of concept. The National Science Foundation supports 17 facilities under its National Nanotechnology Infrastructure Network (NNIN), four of which are focused on nanomanufacturing. The Department of Energy maintains five Nanoscale Science Research Centers, each focused on and specific to a different area of nanoscale research. The National Institutes of Health has a Nanotechnology Characterization Laboratory in Frederick, MD and the National Institute of Standards and Technology maintains a user facility in Gaithersburg, MD. The application processes for each facility varies; however, all are open to academic, government, or industry users. In addition to the user facilities, the NNI is carried out in over 70 centers and institutes[3] throughout the country mostly on university campuses, many of which have user facilities that are open to all applicants.

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[2] Available at *http://www.nano.gov/NNI_EHS_Research_Strategy.pdf*

[3] Information of NNI related user facilities and centers and institutes can be found at *www.nano.gov.*

SBIR/STTR Programs

P.L. 108–153 encourages support for nanotechnology related projects through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs by requiring the National Science and Technology Council to "develop a plan to utilize federal programs, such as the Small Business Innovation Research Program and the Small Business Technology Transfer Research Program, in support of the [NNI activities]. . .." Despite the lack of a formal plan, the SBIR and STTR programs have been used as a vehicle to bring nanotechnology research developed by small business concerns closer to commercialization. The total SBIR and STTR program spending in all technology areas in FY 2006 was nearly $2.2 billion, of that budget $79.7 million was identified as nanotechnology related research.[4] This was 3.7 percent of the total SBIR/STTR spending in FY 2006 and included nine federal agencies. SBIR/STTR funding is allowable for development of technologies from concept to prototype; however, funding of scale-up to manufacturing does not fall within the SBIR/STTR scope of funding.

5. Witness Questions

All witnesses were asked to give their views on the provisions of the bill, including any recommendations for ways to improve it. The list of overarching questions (item 3 above) was included in the invitation letters.

[4] *The National Nanotechnology Initiative Supplement to the President's FY 2008 Budget.* July 2007, p. 24.

Appendix

SECTION-BY-SECTION SUMMARY OF DRAFT NATIONAL NANOTECHNOLOGY INITIATIVE (NNI) AMENDMENTS BILL

SEC. 1. Short Title

National Nanotechnology Initiative Amendments Act of 2008.

SEC. 2. Amendments to the 2003 Act

Modifies the NNI strategic plan to require specification of (1) both near and long-term objectives, (2) the timeframe for achieving near-term objectives, (3) the metrics for measuring progress toward objectives, and (4) multi-agency funded projects in areas of significant economic and societal impacts (see SEC. 5).

Authorizes agencies participating in the NNI to support travel expenses for scientists to participate in standards setting activities related to nanotechnology.

Provides an explicit funding source for the National Nanotechnology Coordination Office (NNCO)—each participating agency provides funds in proportion to the agency's fraction of the overall NNI budget—and requires the NNCO to report annually on its current and future budget requirements, including funding needed to create and maintain new public databases (see following provision) and to fulfill the public input and outreach requirements specified in the 2003 Act.

Requires the NNCO to (1) develop a public database for projects funded under the Environmental, Health and Safety (EHS), Education and Societal Dimensions, and Nanomanufacturing program component areas, with sub-breakouts for education and ELSI projects; and (2) develop, maintain and publicize information about nanotechnology facilities available for use by academia and industry.

Specifies that the NNI Advisory Panel must be a stand-alone advisory committee (at present the President's Council of Advisors for Science and Technology is assigned this role).

Requires the NNI Advisory Panel to establish a sub-panel with members having qualifications tailored to assessing the societal, ethical, legal, environmental, and workforce activities supported by the NNI.

Revises the charge to the National Research Council (NRC) for the content and scope of the triennial reviews of the NNI.

Provides an explicit funding authorization to OSTP of $500K/year for FY09–11 for the NRC triennial reviews.

SEC. 3. Societal Dimensions of Nanotechnology

Assigns responsibility to an OSTP associate director (to be determined by the OSTP Director) to fulfill the role of Coordinator for the societal dimensions component of NNI. The coordinator is (1) responsible for ensuring the strategic plan for EHS is completed and implemented; (2) serves as the focal point for encouraging and advocating buy-in by the agencies, and monitoring their compliance, in providing the resources and management attention necessary; and (3) is responsible for encouraging the agencies to explore suitable mechanisms for establishing public-private partnerships for support of EHS research.

Requires the Coordinator to convene and chair a panel of representatives from agencies supporting research under the EHS program component area to develop, annually update, and coordinate the implementation of a research plan for this program component. The plan, which is to be appended to the statutorily required NNI annual report, must contain near- and long-term research goals and milestones, include multi-year funding requirements by agency and by goal, and take into consideration the recommendations of the NNI Advisory Panel and the agencies responsible for environmental and safety regulations. The plan must include standards development activities related to nomenclature, standard reference materials, and testing methods and procedures.

Requires that at least 10 percent of the total NNI budget be allocated to the EHS program component area.

Establishes Nanotechnology Education Partnerships as part of the NSF Math and Science Partnership (MSP) program to recruit and help prepare secondary school students to pursue post-secondary education in nanotechnology. These partnerships are similar to other MSPs, but must include one or more businesses engaged in nanotechnology and focus the educational activities on curriculum development, teacher professional development, and student enrichment (including access by student to nanotechnology facilities and equipment) in areas related to nanotechnology.

Requires the Program to include within the Education and Societal Dimensions program component area activities to support nanotechnology undergraduate edu-

cation, including support for course development, faculty professional development, and acquisition of equipment and instrumentation. To carry out these activities, the bill authorizes an additional $5M per year for FY 2009 and FY 2010 for the NSF Course, Curriculum, and Laboratory Improvement program (undergraduate STEM education program open to all institutions of higher education) and an additional $5M per year for FY 2009 and FY 2010 for the NSF Advanced Technological Education program (open only to two-year institutions).

Requires formation of an Education Working Group to coordinate, prioritize, and plan the educational activities funded under NNI.

SEC. 4. Technology Transfer

Requires agencies supporting nanotechnology research facilities under NNI to allow, and encourage, use of these facilities to assist companies in developing prototype products, devices, or processes for determining proof of concept. The agencies are required to publicize the availability of these facilities and provide descriptions of the capabilities of the facilities and the procedures and rules for their use.

Requires agencies to encourage applications for support of nanotechnology projects under SBIR and STTR programs, requires publication of the plan to encourage this within six months (plan originally required under the 2003 Act), and requires a report that will track the success of the programs in attracting and supporting nanotechnology projects.

Requires NIST to encourage submission of proposals under the Technology Innovation Program (TIP) for support of nanotechnology related projects and to report to Congress on how this is to be accomplished and on the outcome of the effort over time. Requires the TIP Advisory Board to provide advice to the program on ways to increase the number of nanotechnology related proposals and to assess the adequacy of funding provided for such proposals.

Encourages the creation of industry liaison groups in all relevant industry sectors (four currently exist) and specifically suggests establishing one focused on companies that produce and use composite materials.

Adds to the activities enumerated by the 2003 Act that are required to be carried out under the NNI the coordination and leveraging of federal investments with nanotechnology research, development, and technology transition initiatives supported by the states.

SEC. 5. Research in Areas of National Importance

Requires the NNI to include support for large-scale research and development projects involving collaborations among universities, industry, federal labs, and nonprofit research organizations to accelerate development of promising nanotechnology research discoveries toward near-term solutions to problems in areas of national importance, such as electronics, energy efficiency, health care, and water remediation.

Requires that the competitive, merit based selection process for awards and the funding of these awards be carried out through a collaboration between at least two agencies and that the award selection process take into favorable consideration the availability of cost sharing from non-federal sources.

Project awards may be for support of interdisciplinary research centers, and all must include a plan for transferring technology developed under the projects to industry.

SEC. 6. Nanomanufacturing Research

Specifies inclusion of research under the Nanomanufacturing program component area to include projects to develop instrumentation/tools for rapid characterization and monitoring for nanoscale manufacturing and to develop techniques for scaling nanomaterial synthesis to industrial-level production rates.

Requires that centers established under the NNI on nanomanufacturing and on applications in areas of national importance (SEC. 5) include support for interdisciplinary research and education on methods and approaches to develop environmentally benign nanoscale products and nanoscale manufacturing processes.

Requires a public meeting and subsequent review by the NNI Advisory Panel of the adequacy of the funding level and the relevance to industry's needs of research under the Nanomanufacturing program component area.

SEC. 7. Definitions

Chairman GORDON. Good morning. This hearing will come to order, and I want to welcome everyone to today's hearing to review a draft Committee bill on the amendment in order to amend and strengthen the National Nanotechnology Initiative. I think this is one of the most important hearings that we're going to have this year. I know that we have a busy day for Members in other committees, but we have a lot of staff watching this on TV; and so there will be a lot of information that will be communicated from the hearing, and I appreciate you again being here.

The term revolutionary technology has become a cliché, but nanotechnology truly is revolutionary. We stand at the threshold of an age in which materials and devices can be fashioned atom-by-atom to satisfy specified design requirements. Nanotechnology-based applications are arising that were not even imagined a decade ago.

Nanotechnology is not a single technology, but rather is a collection of tools and concepts for observing, controlling, and manipulating matter at the atomic scale.

The range of potential applications is broad and will have enormous consequences for electronics, energy transformation and storage, materials, and medicine and health, to name just a few. Indeed, the scope of this technology is so broad as to leave virtually no product untouched.

The Science and Technology Committee recognized the promise of nanotechnology early on, holding our first hearing a decade ago to review federal activities in the field. The Committee was subsequently instrumental in the development and enactment of a statute in 2003 that authorized the interagency National Nanotechnology Initiative, or the NNI. The 2003 statute put in place formal interagency planning, budgeting, and coordinating mechanisms for NNI. It now receives funding from 13 agencies and has a budget of $1.5 billion for fiscal year 2008, which represents a doubling of the budget over the last five years.

The NNI statute also provides for formal reviews of the content and management of the program by the National Academies and by a designated advisory committees of non-government experts. Their assessments of NNI have been generally positive.

The cooperation and planning processes among the participating agencies in the NNI have been also largely effective. The NNI has led to productive, cooperative research efforts across a spectrum of disciplines. It has established a network of national facilities for support of nanoscale research and development.

Therefore, the NNI does not require extensive renovation. The draft bill leaves its major features unchanged but does adjust some important priorities and strengthen some specific aspects of the program. I would like to highlight two key features of the bill.

The first area is risk reduction. Nanotechnology is advancing rapidly. At least 600 products have entered commerce that contain nanoscale materials, including aerosols and cosmetics.

It is important for the successful development of nanotechnology that potential downsides of the technology be addressed from the beginning in a straightforward and open way.

We know too well that negative public perceptions about the safety of technology can have serious consequences for its accept-

ance and use. This has been the case with nuclear power, genetically modified foods, and stem cell therapies.

The science base is not now available to pin down what types of engineered nanomaterials may be dangerous, although early studies show some are potentially harmful. We don't yet know what characteristics of these materials are most significant to determine their effect on living things or the environment, nor do we even have the instruments for effectively monitoring the presence of such materials in the air or water.

Although the NNI has from its beginning realized the need to include activities for increasing understanding of the environmental and safety aspects of nanotechnology, it has been slow to put in place a well-designed, adequately-funded, and effectively executed research program.

The environmental and safety component of NNI must be improved by quickly developing and implementing a strategic research plan that specifies near-term and long-term goals, sets milestones and timeframes for meeting near-term goals, clarifies agencies' roles in implementing the plan, and allocates sufficient resources to accomplish the goals.

This is the essential first step for the development of nanotechnology to ensure that sound science guides the formulation of regulatory rules and requirements. It will reduce the current uncertainty that inhibits commercial development of nanotechnology and will provide a sound basis for future rule-making.

I am interested in hearing the views of our witnesses on the provisions of the bill relevant to the development and implementation of an effective environmental, health and safety research component of the NNI, and particularly, on whether it would be beneficial to specifically set aside a portion of the overall NNI budget for this purpose as is proposed in this bill.

The second area of the legislation I want to highlight involves capturing the economic benefits of nanotechnology.

Too often the U.S. has led in the basic research on the frontiers of science and technology but has failed to capitalize on the commercial developments flowing from new discoveries.

The NNI has so far invested approximately $7 billion over seven years in basic research that is providing new tools for the manipulation of matter at the nanoscale and is increasing our understanding of the behavior of engineered nanoscale materials and devices. Increased consideration should now be given to support efforts to foster the transfer of new discoveries to commercial products and processes.

The draft bill includes provisions to encourage use of nanotechnology facilities by companies for prototyping and proof of concept studies, and it specifies steps for increasing the number of nanotechnology-related projects supported under the Small Business Innovation Research Program and by the Technology Innovation Program, established under the COMPETES Act.

To increase the relevance and value of the NNI, the draft bill also authorizes large-scale, focused, multi-agency research and development initiatives in areas of national need.

For example, such efforts could be organized around developing a replacement for the silicon-based transistor, developing new nanotechnology-based devices for harvesting solar energy, or nanoscale sensors for detecting cancer.

The draft NNI Amendments Act was developed on the basis of recommendations from the formal reviews of the NNI by the National Academy of Sciences and by the President's Council of Advisors for Science and Technology, which currently acts as the external advisory committee to NNI. It also incorporates recommendations from witnesses' testimony from NNI hearings during this and the previous Congress and from comments and recommendations resulting from staff discussions with various stakeholder groups.

This legislation is still a work in progress. Today I look forward to the observations of our witnesses and invite them to give the Committee their recommendations for ways to improve the bill.

I want to thank our witnesses for their attention at this hearing and look forward to our discussion.

[The prepared statement of Chairman Gordon follows:]

PREPARED STATEMENT OF CHAIRMAN BART GORDON

I want to welcome everyone to this morning's hearing to review a draft Committee bill to amend and strengthen the National Nanotechnology Initiative.

The term "revolutionary technology" has become a cliché, but nanotechnology truly is revolutionary. We stand at the threshold of an age in which materials and devices can be fashioned atom-by-atom to satisfy specified design requirements. Nanotechnology-based applications are arising that were not even imagined a decade ago.

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The 2003 statute put in place formal interagency planning, budgeting, and coordinating mechanisms for NNI. It now receives funding from 13 agencies and has a budget of $1.5 billion for fiscal year 2008, which represents a doubling of the budget over five years.

The NNI statute also provides for formal reviews of the content and management of the program by the National Academies and by a designated advisory committee of non-government experts. Their assessments of NNI have been generally positive.

The cooperation and planning processes among the participating agencies in the NNI have been largely effective. The NNI has led to productive, cooperative research efforts across a spectrum of disciplines, and it has established a network of national facilities for support of nanoscale research and development.

Therefore, the NNI does not require extensive renovation. The draft bill leaves its major features unchanged, but does adjust some important priorities and strengthen some specific aspects of the program. I would like to highlight two key features of the bill.

The first area is risk reduction. Nanotechnology is advancing rapidly, and at least 600 products have entered commerce that contain nanoscale materials, including aerosols and cosmetics.

It is important for the successful development of nanotechnology that potential downsides of the technology be addressed from the beginning in a straightforward and open way.

We know too well that negative public perceptions about the safety of a technology can have serious consequences for its acceptance and use. This has been the case with nuclear power, genetically modified foods, and stem cell therapies.

The science base is not now available to pin down what types of engineered nanomaterials may be dangerous, although early studies show some are potentially harmful. We don't yet know what characteristics of these materials are most significant to determine their effects on living things or on the environment.

Nor do we even have the instruments for effectively monitoring the presence of such materials in air or water.

Although the NNI has from its beginnings realized the need to include activities for increasing understanding of the environmental and safety aspects of nanotechnology, it has been slow to put in place a well designed, adequately funded, and effectively executed research program.

The environmental and safety component of NNI must be improved by quickly developing and implementing a strategic research plan that specifies near-term and long-term goals, sets milestones and timeframes for meeting near-term goals, clarifies agencies' roles in implementing the plan, and allocates sufficient resources to accomplish the goals.

This is the essential first step for the development of nanotechnology to ensure that sound science guides the formulation of regulatory rules and requirements. It will reduce the current uncertainty that inhibits commercial development of nanotechnology and will provide a sound basis for future rule-making.

I am interested in hearing the views of our witnesses on the provisions of the bill relevant to the development and implementation of an effective environmental, health and safety research component for the NNI, and particularly, on whether it would be beneficial to specifically set aside a portion of the overall NNI budget for this purpose, as is proposed in the draft bill.

The second area of the legislation I want to highlight involves capturing the economic benefits of nanotechnology.

Too often the U.S. has led in the basic research on the frontiers of science and technology but has failed to capitalize on the commercial developments flowing from new discoveries.

The NNI has so far invested approximately $7 billion over seven years in basic research that is providing new tools for the manipulation of matter at the nanoscale and is increasing our understanding of the behavior of engineered nanoscale materials and devices. Increased consideration should now be given to support of efforts to foster the transfer of new discoveries to commercial products and processes.

The draft bill includes provisions to encourage use of nanotechnology facilities by companies for prototyping and proof of concert studies, and it specifies steps for increasing the number of nanotechnology related projects supported under the Small Business Innovation Research Program and by the Technology Innovation Program, established under the COMPETES Act.

To increase the relevance and value of the NNI, the draft bill also authorizes large-scale, focused, multi-agency research and development initiatives in areas of national need.

For example, such efforts could be organized around developing a replacement for the silicon-based transistor, developing new nanotechnology-based devices for harvesting solar energy, or nanoscale sensors for detecting cancer.

The draft NNI Amendments Act was developed on the basis of recommendations from formal reviews of the NNI by the National Academy of Sciences and by the President's Council of Advisors for Science and Technology, which currently acts as the external advisory committee for NNI. It also incorporates recommendations from witness testimony from NNI hearings during this and the previous Congress and from comments and recommendations resulting from staff discussions with various stakeholder groups.

This legislation is still a work in progress. Today I look forward to the observations of our witnesses and invite them to give the Committee their recommendations for ways to improve the bill.

I want to thank our witnesses for their attendance at this hearing and look forward to our discussion.

Chairman GORDON. The Chair now recognizes Mr. Ehlers for an opening statement.

Mr. EHLERS. Thank you, Mr. Chairman, but first I must mention that Ranking Member Ralph Hall is indisposed today which means he is sick, and it takes quite a bit to keep a Texan down. So he sends his regrets, and Mr. Chairman, I ask unanimous consent that Mr. Hall's statement be entered into the record, and I will proceed with my own statement.

I am pleased the Committee is holding this important hearing today. The purpose of this hearing is to discuss draft reauthorization legislation designed to improve the management and coordination of the cross-agency National Nanotechnology Initiative, better known as NNI. Of particular interest to this committee is the prioritization of environmental, health, and safety research and communication of that research to the public.

Since the original Act was put in place in 2003, we have heard from a number of witnesses that EHS research may need to be increased to ensure a steady pathway for both the nano industry success and public acceptance of new technologies. Consequently, I am pleased that the draft legislation elevates the environmental, health, and safety component of the NNI. At the same time, I want to make sure we craft policy which allows for EHS research to be embedded into product development. We know that each nano product and process may behave differently, and therefore, independent EHS research may not always inform a seemingly parallel project.

I am also interested in hearing from our witnesses about some of the proposed changes to nanotechnology education, particularly the changes to existing education programs at the National Science Foundation. Given the challenging funding environment for these programs, I want to make sure such changes would benefit students and classroom teachers and not eat away at other important programs.

I look forward to hearing the insights of our witnesses on how we can strengthen the National Nanotechnology Initiative so that the United States can remain a leader in nanotechnology.

Mr. Chairman, with that, I yield back the balance of my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you Chairman Gordon. I was pleased to be an original co-sponsor of the *21st Century Nanotechnology Research and Development Act,* which established our national nanotechnology program in 2003. It was the right thing to do, and thus far, has proven to be successful. I hope that we can continue to work together to ensure that the reauthorization of this vital program before us can move forward in a bipartisan fashion and with bipartisan support.

This committee has spent some time focusing on various aspects of nanotechnology at the Subcommittee level, much of which has been incorporated into the draft legislation before us today. I do not need to spend a lot of time talking about the potential benefits and challenges of nanotechnology to our society. Mr. Chairman, you and I, as Co-Chairs of the Nanotechnology Caucus and as Members of this committee for many years, are well aware of them, and I am certain our witnesses may have a point or two to make about them as well. Suffice it to say, despite its name, this is no small issue. Our scientists are using nanotechnology to help create clean, secure affordable energy; low-cost filters to provide clean drinking water; medical devices and drugs; sensors to detect and identify harmful chemical and biological agents; and techniques to clean up hazardous chemicals in the environment. And this is just the beginning of the list.

I recognize that as these nanotechnologies are being developed, we have a responsibility to mitigate potential environmental, health and safety (EHS) risks, as we do with any new technology. This work is currently being done and as long as the need is there, agencies should continue to fund EHS research, but it should not necessarily take precedence over or be funded at the expense of the other component areas identified in the strategic plan. My main interest, as we move forward with this bill, is to make sure that we are careful to allow a multi-agency program, which seems to be working well, to continue to have the flexibility needed to do its work without being too prescriptive. We can tweak it a bit, but we certainly do not need

to fix something that is not broken and, in fact, serves as a good model for how an interagency program should work.

We have before us a well-rounded and esteemed panel of experts with different interests in nanotechnology, and I look forward to hearing their views on this bill and on ways that we can work to make improvements to it.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Thank you Chairman Gordon. I am pleased that the Committee is holding this important hearing today.

The purpose of this hearing is to discuss draft reauthorization legislation designed to improve the management and coordination of the cross-agency National Nanotechnology Initiative (NNI). Of particular interest to this committee is the prioritization of environmental, health and safety (EHS) research and communication of that research to the public.

Since the original Act was put in place in 2003, we have heard from a number of witnesses that EHS research may need to be increased to ensure a steady pathway for both the nano-industry success and public acceptance of new technologies. Consequently, I am pleased that the draft legislation elevates the EHS component of the NNI. At the same time, I want to make sure we craft policy which allows for EHS research to be embedded into product development. We know that each nano-product and process may behave differently, and therefore independent EHS research may not always inform a seemingly parallel project.

I am also interested in hearing from our witnesses about some of the proposed changes to nanotechnology education, particularly the changes to existing education programs at the National Science Foundation. Given the challenging funding environment for these programs, I want to make sure such changes would benefit students and classroom teachers and not eat away at other important programs.

I look forward to hearing the insights of our witnesses on how we can strengthen the National Nanotechnology Initiative so that the United States can remain a leader in nanotechnology. Mr. Chairman, I yield back the balance of my time.

Chairman GORDON. Thank you, Dr. Ehlers. It has come to my attention that Mr. Honda, former and valued Member of the Science Committee, is in the audience; and I would ask unanimous consent that Mr. Honda be allowed to join this hearing if he so chooses, and you're welcome to take a seat here. I would also remind Mr. Honda as he remembers from being a Member of the Committee that the current Members will have precedence in terms of asking questions, but we certainly want his expertise and we are glad that he is here to join us. If there is no objection, Mr. Honda will join us.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. I want to extend a special, warm welcome to Dr. Robert R. Doering, who is with Texas Instruments.

T.I. is a power player in Texas and throughout the Nation.

In addition to their nanotechnology research and semiconductor industry prominence, T.I. is a good neighbor.

The company has worked hard to reach out to schools in Dallas. By providing extra attention to students in under-served areas, T.I. has brought up test scores and generated interest in high-tech careers among our young people.

That's good citizenship.

So, I want to commend industry for its role in educating tomorrow's high-tech workforce.

During previous hearings held by this committee, the witnesses, who represented the Federal Government, industry, and educational institutions and science educators at all levels, agreed that nanotechnology education is an important component of a strategy to capitalize on the promise of this advancing field.

Witnesses discussed the importance of early nanotechnology education for generating enthusiasm among young students and the general public.

They were unanimous in their support for increasing formal education in nanotechnology beginning at the undergraduate level, including at two-year colleges because of their important role in developing a skilled workforce.

I will be interested to hear how best to allocate our resources, as this committee works to reauthorize the National Nanotechnology Initiative.

To me, it seems that the priority should be to ensure that we have the domestic workforce in place. That, Mr. Chairman, begins with educational activities.

Again, I want to welcome today's witnesses and thank the Chairman and Ranking Member for holding today's hearing.

I yield back the balance of my time.

[The prepared statement of Mr. Mitchell follows:]

PREPARED STATEMENT OF REPRESENTATIVE HARRY E. MITCHELL

Thank you, Mr. Chairman.

The advanced development of nanoscale technology has the potential to impact virtually every sector of our economy as well as our daily lives.

Here in the United States, we are currently the leader in nanotechnology research and development. However, we must continue to protect and ensure U.S. leadership in nanotechnology R&D.

The National Nanotechnology Initiative (NNI) has played a vital role in supporting nanotechnology activities in 25 federal agencies.

However, as this committee has found, it is essential to ensure that the NNI continues to focus on modern issues facing nanotechnology development today.

As a former teacher for almost 30 years, I strongly support enhancing K–16 nanotechnology-related education programs. As we addressed in the *America COMPETES Act,* it is critical to ensure that our workforce is educated and prepared to continue to lead in nanotechnology R&D.

I look forward to hearing more from our witnesses.

I yield back.

Chairman GORDON. At this time, I would like to introduce our witnesses. First, Mr. Floyd Kvamme is the Co-Chair of the President's Council of Advisors on Science and Technology. Mr. Sean Murdock is the Executive Director for the NanoBusiness Alliance. Dr. Joseph Krajcik is the Associate Dean of Research and Professor of Education at the University of Michigan. Mr. Ehlers, I hope you will be happy about that. Dr. Andrew Maynard is the Chief Science Advisor for the Project of Emerging Nanotechnologies at the Woodrow Wilson Center for Scholars. Dr. Raymond David is the Manager of Toxicology at BASF Corporation and is also representing the American Chemistry Council. Finally, Dr. Robert Doering. Dr. Doering is a Senior Fellow and Research Strategy Manager at Texas Instruments and is also representing the Semiconductor Industry Association. Thank you for joining us today, and we have a very distinguished panel at this point. We will open our first round of questions—excuse me. I guess we should hear from our witnesses, shouldn't we? Let us begin.

STATEMENT OF MR. E. FLOYD KVAMME, CO-CHAIR, PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY

Mr. KVAMME. My name is Floyd Kvamme. I am Co-Chair of the President's Council of Advisors on Science and Technology, a high-level group from academia, industry, and other entities experienced in leading successful science and technology enterprises. My remarks today are my own, but I am confident that my fellow PCAST members feel similarly on the issues under discussion.

Last week, PCAST released its second review of the National Nanotechnology Initiative, or NNI, and I'd like to reference that report in full for this hearing's record, as it includes a detailed assessment of NNI program activities and coordination developed through extensive review over the last 18 months.

We are here today to talk about the NNI and the Committee's draft legislation to reauthorize this important program. What is nanotechnology? If one drops the nano part of the word, we are talking about technology. Technology today invades every part of our economy, not only computers and communications, but health care, energy, transportation, education, and in a word, everything. As a result, a technology initiative is about a very wide and varied range of industries and applications. Nanotechnology is simply the continuing development of technology to applications which take advantage of the unique properties of some materials and is being applied in all of the applications mentioned above and will, undoubtedly, make many of the products in these applications better, either in performance, cost or both.

Establishment of the NNI was a very good idea. I commend the Congress and this committee for authorizing this initiative in 2003. In both our first report in 2005 and now our second one, we have had to deal not only with the diversity that is nanotechnology but also a wide range of federal agencies involved in supporting and/or conducting nano R&D. The initiative did not set up a new agency with a specific budget; rather, it set up coordination, planning, and review mechanisms intended to ensure individual agency activities in nanotechnology are effectively supporting program and government-wide goals. The legislation formally established the coordinating office which raises its budget through contributions from the various agencies with nanotechnology R&D budgets. Agencies with primarily regulatory missions have also taken an active role in the initiative and have contributed to its activities. This strong and interagency coordination, a premier example of any such Federal R&D initiative, has been central to the success to date of the NNI.

Appropriate and informed support for environmental, health and safety (EHS), research within the NNI is an important responsibility that demands strong coordination. With respect to EHS, PCAST has found that the NNI's approach has been sound; the interagency coordination process identified EHS research needs, mapped those needs to current activities to identify potential research opportunities, and then prioritized those opportunities to inform budget and planning activities.

The provision of the draft reauthorizing legislation that the NNI collectively allocate a minimum of 10 percent of its nanotechnology R&D to EHS-related research is, however, problematic in both practice and principle. In practice the funding of each agency is independent of the NNI. The NSET subcommittee provides the base for coordinating member agency activities and planning efforts, but it does not direct NNI funding. Further, it is not reasonable to exclusively designate projects or portions of projects as exclusively EHS or not. The reporting structure of the NNI by PCAs enables characterization and analysis of the research portfolio that is sufficient for policy and planning purposes. The current funding mechanisms and structure makes it difficult for me to see how this minimum funding across the program is practical. In principle, the set-aside appears to be arbitrary and not based on a sound scientific analysis of the NNI portfolio of relevant research, including extensive relevant research not reported in the EHS component

area and what is strategically needed. Instead, support should be guided by the identified gaps in sequential priorities identified in the EHS research strategy. Like all other aspects of the NNI, EHS research funding decisions should be determined by identified R&D directives as is currently the approach of the agencies within the NNI. Scientifically determined, strategically planned priorities, not arbitrary percentages, should guide funding for all nanotechnology research.

With respect to the oversight provisions, the breadth and depth of the high-level experience of the PCAST and its role as the National Nanotechnology Advisory Panel, combined with a detailed expertise of the ad hoc technology advisory group, has worked quite well the last five years in providing functional oversight for the NNI and directly advising the President on nanotechnology. The proposed bill should maximize the flexibility for the next Administration in establishing its own advisory structure. As the current PCAST prepares to pass the baton to the next administration, we will suggest they incorporate a similar approach to oversight, leveraging the expertise of a large technical advisory group, whether they be within PCAST or separate.

In summary, the NNI as currently structured is a productive and effective program and a model of interagency coordination. Our newly released report makes recommendations for improvement but finds the program basically sound. Industry is benefiting from its research. A clear strategy has been developed for nanotechnology-related EHS research, and EHS guidelines are being presented to guide industry. International cooperation is happening. The Coordinating Office and NNI participating agencies have responded to past recommendations from PCAST as well as the National Academies and have strengthened the program. Agencies participate voluntarily because they derive benefit from doing so. A reauthorization that avoids overly prescriptive guidance, like an arbitrary EHS funding floor, and bureaucratic micro-management, such as costly database requirements, will further strengthen and promote interagency coordination that has been vital to the success of the NNI to date. This approach would confirm the goals as presented in the original legislation and commend the agencies for their coordinated efforts to maintain the leadership and competitiveness of the U.S. in nanotechnology.

Thank you.

[The prepared statement of Mr. Kvamme follows:]

PREPARED STATEMENT OF E. FLOYD KVAMME

Mr. Chairman and Members of the Committee, I am pleased to testify today. My name is Floyd Kvamme. I am Co-Chair of the President's Council of Advisors on Science and Technology (or PCAST). PCAST comprises a high-level group from academia, industry, and other entities with experience in leading successful science and technology enterprises. My remarks today are my own, but based on our recent review, I am confident that my fellow PCAST members feel similarly on the issues under discussion today.

Last week, PCAST released its second review of the National Nanotechnology Initiative (or the NNI), and I'd like to reference that report in full for this hearing's record. That review, required by Congress as the primary external advisory mechanism for the NNI, includes a detailed assessment of NNI program activities and coordination developed through extensive review and consultation by PCAST members over the last 18 months. The executive summary of the report is attached to this

testimony and I recommend it for your review (full report available at: *http://www.ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf*).

We are here today to talk about the NNI and the Committee's draft legislation to reauthorize this important interagency research and development (R&D) program. Let me begin by giving you my view of what *nanotechnology* is. If one drops the 'nano' part of the word, we are talking about 'technology.' Technology today invades virtually every part of our economy. It's not only computers and communications, but health care, energy, transportation, education, and—in a word—everything. As a result, in talking about a "technology initiative," we are talking about a very wide and varied range of industries and applications. Nanotechnology is simply the continuing development of technology to applications which take advantage of the unique properties of some materials engineered at the nanoscale. Nanotechnology is being applied in virtually all of the applications mentioned above and will, undoubtedly, make many of the products in these applications better—either in performance, cost or both. We should not think of some narrow range of applications for nanotechnology, but rather a vast array of potential uses.

Establishment of the NNI was a very good idea. I commend the great work of Congress and this committee for formally authorizing this initiative in 2003. In both our first report in 2005 and now our second one released last week, we have had to deal not only with the diversity that is nanotechnology but also a wide range of federal agencies involved in supporting and/or conducting nano R&D. Appropriately, the initiative did not set up a new agency with a specific budget; rather, it set up coordination, planning, and review mechanisms intended to ensure individual agency activities in nanotechnology are effectively supporting program- and government-wide goals. I believe recognizing this is important and instructive with respect to the draft legislation, and I'll get to that in a few moments. The legislation did formally establish the coordinating office which raises its budget through contributions from the various agencies with nanotechnology R&D budgets. Agencies with primarily regulatory missions have also taken an active role in the initiative and have contributed to its activities. This strong and deep interagency coordination—a premier example of any such Federal R&D initiative—has been central to the success to date of the NNI.

At the same time, the agencies have specific missions and objective to address. For example, appropriate and informed support for environmental, health and safety (EHS) research within the NNI is an important responsibility that demands strong coordination. With respect to this issue PCAST has found that the NNI's approach has been sound; the interagency coordination process identified EHS research needs, mapped those needs to current activities to identify potential research opportunities, and then prioritized those opportunities to inform budget and planning activities. For example, I refer you to page 49 of the recently-released NNI *Strategy for Nanotechnology-Related Environmental, Health, and Safety Research* (full report available at *http://www.nano.gov/NNI_EHS_Research_Strategy.pdf*):

Research Need / Agency	Instrument., Metrology, and Analytical Methods	Nanomtls. and Human Health	Nanomtls. and the Environment	Human & Environmental Exposure Assessment	Risk Management Methods
NIH	○□	◆	□	□	
NIST	◆	○	○	○	○
EPA	○□	○□	◆	○□	◆
FDA	□	□	□	□	◆
NIOSH	○□	○□	○	◆	○□
NSF	○	○	○	○	○
DOD	□	□	○□	□	○□
DOE	○□	□	○□	□	□
USDA/CREES	□	○□	○□	□	□
DOT		□	□	□	□
OSHA	□	□		□	□
CPSC	○□	□	□	○□	○□
USGS	○□		○□	○□	

◆ - Coordinating Agency
Leadership role in coordinating and communicating with other NNI agencies

○ - Contributor
Have funded or are planning to fund or conduct research in category

□ - User
Have expressed a need for, or expectation to make use of, research outputs or information to support missions & responsibilities

In this document the Nanoscale Science, Engineering, and Technology Subcommittee's working group on Nanotechnology Environmental and Health Implications (or NEHI) has developed five critical areas for EHS research. The agencies agreed to cooperate such that while there was a lead agency for each task, the other agencies contribute to the overall goals agreed to within the NNI. These efforts do not take away from the other work within the agencies to perform their mission-oriented functions but, in our view, lead to more effective activity within the lead agency. I point specifically to the reports and activities of NIOSH, EPA, FDA, and NIST (detailed on page 27 in our PCAST report) as examples of agency specific activity:

- The OSTP and the Council on Environmental Quality (CEQ) issued in November 2007 a memorandum identifying principles for nanotechnology environmental health and safety oversight based on interagency consensus.[1]
- The National Institute of Occupational Safety and Health (NIOSH) issued a call in July 2006 for information in *Approaches to Safe Nanotechnology*[2] inviting expert feedback from private industry and other government entities, and in June 2007 it issued the report *Progress Toward Safe Nanotechnology in the Workplace.*[3]
- The Environmental Protection Agency (EPA) produced in February 2007 a white paper[4] summarizing the agency's anticipated approach to nanotechnology EHS research, followed in February 2008 by a nanomaterial research strategy.[5] The agency also has launched a Voluntary Nanoscale Materials stewardship program.
- The Food and Drug Administration (FDA) released in July 2007 the report[6] of its Nanotechnology Task Force's efforts to clarify a predictable pathway for application of existing regulatory approaches on a case-by-case basis for developers of nanotechnology-enabled products under its jurisdiction.
- NIST is producing standard reference materials for nanoscale gold and carbon nanotubes.

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[1] *http://www.ostp.gov/galleries/default-file/Nano%20EHS%20Principles%20Memo_OSTP-CEQ_FINAL.pdf*
[2] *http://www.cdc.gov/niosh/topics/nanotech/safenano/*
[3] *http://www.cdc.gov/niosh/docs/2007-123/*
[4] *http://es.epa.gov/ncer/nano/publications/whitepaper12022005.pdf*
[5] *http://es.epa.gov/ncer/nano/publications/nano_strategy_012408.pdf*
[6] *http://www.fda.gov/nanotechnology/taskforce/report2007.pdf*

The provision in the draft reauthorizing legislation that the NNI collectively allocate a minimum of 10 percent of its nanotechnology R&D to EHS-related research is problematic in both *practice* and *principle:*

- *In practice,* the funding of each agency is fundamentally independent of the NNI. The NSET Subcommittee of the National Science and Technology Council provides the base for coordinating NNI member agencies activities and planning efforts, but it does not direct NNI funding. Furthermore, it is not feasible or reasonable to exclusively designate projects (or portions of projects) as exclusively "EHS" or not. The current reporting structure of the NNI by Program Component Areas or PCAs enables characterization and analysis of the research portfolio that is sufficient for policy and planning purposes. The current funding mechanisms and structure of the NNI makes it difficult for me to see how this "minimum funding" across the program is either reasonable, necessary, or, indeed, practical.
- *In principle,* this set-aside appears to be arbitrary and not based on a sound scientific analysis of the current NNI portfolio of relevant research (including extensive relevant research not reported under the EHS program component area) and what is strategically needed. Instead, support should be guided by the identified gaps and sequential priorities identified in the NNI's nanotechnology EHS research strategy. Like all other aspects of the NNI, EHS research funding decisions should be determined by identified R&D objectives, as is currently the approach of the agencies within the NNI. **Scientifically-determined, strategically-planned priorities—not arbitrary percentages—should guide funding for all nanotechnology research, including research relevant to EHS.**

It is important to note that funding for nano-related EHS research has doubled since 2005. As industry picks up more applications research, the Federal Government's role will change and is already changing to work more in the EHS and regulatory areas. EHS funding will probably continue to increase. The one area where funding is accelerating—perhaps tied to our recommendations—is in worker safety where we will propose in our upcoming letter on the EHS report that NIOSH spending accelerate. The reason worker spending is so critical is that in many instances, nanomaterials—while in nano form in the workplace—stop being nanomaterials after production and become a tightly, chemically bound part of a larger system.

With respect to the oversight provisions in the proposed reauthorization, the breadth and depth of high-level expertise of the PCAST in its role as the National Nanotechnology Advisory Panel combined with the detailed expertise of the ad hoc Technical Advisory Group has worked quite well the past five years in providing functional oversight for the NNI and directly advising the President on nanotechnology. The proposed bill should maximize the flexibility for the next Administration in establishing its own advisory structure. As the current PCAST prepares to pass the baton to the next administration, we will suggest they incorporate a similar approach to oversight, leveraging the expertise of a large technical advisory group, whether they be within PCAST or separate.

With respect to overcoming barriers to commercialization and facilitating tech transfer, again I refer to the report of the PCAST review of the NNI. The NNI's unparalleled infrastructure of centers, networks, and user facilities is working very well, geographically distributed and with a wide array of expertise. These facilities are serving their purposes well based on all inputs we have received from both our TAG members and personal experience. Furthermore, the NNI already supports "large-scale research and development projects" on problems of national importance, for example, in energy and biomedicine. The National Cancer Institute, for example, supports a five-year, $144 million program developing nanotechnology for cancer diagnostics and therapeutics that involves eight centers and over 400 investigators.

With respect to overall funding, the NNI seems well funded in balance to other programs in the S&T budget. PCAST had hoped that the *America COMPETES Act* funding would have been passed and will continue to support those priorities of this Congress.

In summary, the NNI as currently structured is a very productive and effective program and a model of interagency coordination. Our newly released report makes recommendations for improvement but finds the program basically sound. Industry is benefiting from its research. A clear strategy has been developed for nanotechnology-related EHS research, and EHS guidelines are being presented to guide industry. International cooperation is happening. The National Nanotechnology Coordinating Office and NNI participating agencies have responded to past recommendations from PCAST as well as the Academies and have strengthened the program. Agencies participate voluntarily because they derive benefit from

doing so. A heavy-handed reauthorization with overly prescriptive guidance (like an arbitrary EHS funding floor) and bureaucratic micro-management (such as costly database requirements) will weaken and inhibit the interagency coordination that is vital to the success of the NNI to date. Rather, this reauthorization should be an opportunity to strengthen and support the interagency coordination founding the NNI, confirming the goals as presented in the original legislation and commending the agencies for their coordinated efforts to maintain the leadership and competitiveness of the U.S. in nanotechnology.

Appendix:

Executive Summary of The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel

(April 2008)

The *21st Century Nanotechnology Research and Development Act of 2003* (Public Law 108–153) calls for a National Nanotechnology Advisory Panel (NNAP) to periodically review the federal nanotechnology research and development (R&D) program known as the National Nanotechnology Initiative (NNI). The President's Council of Advisors on Science and Technology (PCAST) is designated by Executive Order to serve as the NNAP. This report is the second NNAP review of the NNI, updating the first assessment published in 2005.

Including the NNI budget request for fiscal year (FY) 2009 of $1.5 billion, the total NNI investment since its inception in 2001 is nearly $10 billion. The total annual global investment in nanotechnology is an estimated $13.9 billion, divided roughly equally among the United States, Europe, and Asia. Industry analysis suggests that private investment has been out-pacing that of government since about 2006. The activities, balance, and management of the NNI among the 25 participating U.S. agencies and the efforts to coordinate with stakeholders from outside the Federal Government, including industry and other governments, are the subject of this report.

The first report answered four questions: How are we doing? Is the money well spent and the program well managed? Are we addressing societal concerns and potential risks? How can we do better? That report was generally positive in its conclusions but provided recommendations for improving or strengthening efforts in the following areas: technology transfer; environmental, health, and safety (EHS) research and its coordination; education and workforce preparation; and societal dimensions.

Since the first report, increasing attention has been focused on the potential risks of nanotechnology, especially the possible harm to human health and the environment from nanomaterials. In this second assessment, the NNAP paid special attention to the NNI efforts in these areas. During its review, the NNAP obtained input from various sources. It convened a number of expert panels and consulted its nanotechnology Technical Advisory Group (nTAG) and the President's Council on Bioethics. NNI member agencies and the National Nanotechnology Coordination Office (NNCO) also provided valuable information.

The NNAP finds that the United States remains a leader in nanotechnology based on various metrics, including R&D expenditures and outputs such as publications, citations, and patents. However, taken as a region, the European Union has more publications, and China's output is increasing. There are many examples of NNI-funded research results that are moving into commercial applications. However, measures of technology transfer and the commercial impact of nanotechnology as a whole are not readily available, in part because of the difficulty in defining what is, and is not, a "nanotechnology-based product."

The NNAP commends and encourages the ongoing NNI investment in infrastructure and instrumentation. Leading-edge nanoscale research often requires advanced equipment and facilities. The NNI investment in over 81 centers and user facilities across the country that provide broad access to costly instrumentation, state-of-the-art facilities, and technical expertise has been enormously important and successful. These facilities, which have been funded by many different agencies in order to address a variety of missions, support a diverse range of academic, industry, and government research. In addition, the NNI investment has been used to leverage additional support by universities, State governments, and the private sector.

Advances in nanotechnology are embodied in a growing number of applications and products in various industries. Many early applications have been more evolutionary than revolutionary. However, research funded by the NNI today has the potential for innovations that are paradigm shifting, for example in energy and medicine. As with any emerging technology, there is potential for unintended consequences or uses that may prove harmful to health or the environment or that may have other societal implications. The NNAP notes that existing regulations

apply to nanotechnology-based products, and those who make or sell such products have responsibilities regarding workplace and product safety. As in 2005, the NNAP believes that the greatest risk of exposure to nanomaterials at present is to workers who manufacture or handle such materials. However, environmental, health, and safety risks in a wide range of settings must be identified and the necessary research performed so that real risks can be appropriately addressed.

The NNAP views the approach for addressing EHS research under the NNI as sound. The recent reports by the interagency Nanotechnology Environmental and Health Implications (NEHI) Working Group are good steps by the NNI to prioritize needed EHS research and to coordinate EHS activity across the Federal Government. The NNAP feels that calls for a separate agency or office devoted to nanotechnology EHS research or to set aside a fixed percentage of the budget for EHS research are misguided and may have the unintended consequence of reducing research on beneficial applications and on risk.

In addition to EHS implications, the NNAP considered ethical and other societal aspects of nanotechnology. **In consultation with the President's Council on Bioethics, the panel concluded that at present, nanotechnology does not raise ethical concerns that are unique to the field.** Rather, concerns over implications for privacy and for equality of access to benefits are similar to concerns over technological advances in general. This finding does not diminish the importance of continued dialogue and research on the societal aspects of nanotechnology.

Overall, the members of the NNAP feel that the NNI continues to be a highly successful model for an interagency program; it is well organized and well managed. The structure of the interagency Nanoscale Science, Engineering, and Technology (NSET) Subcommittee of the National Science and Technology Council effectively coordinates the breadth of nanotechnology activities across the Federal Government. The NSET working groups target functional areas in which additional focus is required. The NNCO provides important support that is a key to the success of the program. The Strategic Plan updated in 2007 clearly communicates the goals and priorities for the initiative and includes actions for achieving progress. With the separation in the updated plan of EHS research from that on other societal dimensions, the NNAP finds the Program Component Areas (PCAs) that are defined for purposes of tracking programs and investments serve the NNI well.

The NNAP has a number of recommendations for strengthening the NNI, which are grouped into six areas.

1. Infrastructure, management, and coordination. The NNAP feels that the substantial infrastructure of multi-disciplinary centers, user facilities, along with instrumentation, equipment, and technical expertise, is vital to continued U.S. competitiveness in nanotechnology and should be maintained. Whereas the NNAP finds the coordination and management among the NNI participating agencies to be generally strong, intra-agency coordination should be improved, especially in large, segmented agencies. The NNI member agencies should continue to support international coordination through effective international forums, such as the Organization for Economic Co-operation and Development (OECD). Such efforts will aid in the development of information related to health and safety, as well as addressing economic barriers and impacts. Implementing and monitoring this recommendation should lead to more effective use of agency resources.

2. Standards development. Nanotechnology standards are necessary for activities ranging from research and development to commerce and regulation. Federal agencies should continue to engage in national and international standards development activities. The NNI should maintain a strong U.S. representation in international forums and seek to avoid duplicative standards development work. Where appropriate, NIST and other NNI agencies should develop reference materials, test methods, and other standards that provide broad support for industry production of safe nanotechnology-based products.

3. Technology transfer and commercialization. The NNI should continue to fund world-class research to promote technology transfer. Strong research programs produce top-notch nanoscale scientists, engineers, and entrepreneurs, who graduate with knowledge, skills, and innovative ideas. Such programs also have the potential to attract more U.S. students to related fields. NNI-funded centers should be structured to spur partnering with industry, which enhances technology transfer. The NNI should seek means to assess more accurately nanotechnology-related innovation and commercialization of NNI research results. These efforts should be coordi-

nated with those of the OECD to assess economic impact of nanotechnology internationally.

4. Environmental, health, and safety implications. The NNAP feels that the NNI has made considerable progress since its last review in the level and coordination of EHS research for nanomaterials. Such efforts should be continued and should be coordinated with those taking place in industry and with programs funded by other governments to avoid gaps and unnecessary duplication of work. Moreover, EHS research should be coordinated with, not segregated from, applications research to promote risk and benefit being considered together. This is particularly important when development and risk assessment research are taking place in parallel, as they are for nanotechnology today. The NNI should take steps to make widely available nonproprietary information about the properties of nanomaterials and methods for risk/benefit analysis.

5. Societal and ethical implications. Research on the societal and ethical aspects of nanotechnology should be integrated with technical R&D and take place in the context of broader societal and ethical scholarship. The NNAP feels that this approach will broaden the range of perspectives and increase exchange of views on topics that affect society at large.

6. Communication and outreach. The NNAP is concerned that public opinion is susceptible to hype and exaggerated statements—both positive and negative. The NNI should be a trusted source of information about nanotechnology that is accessible to a range of stakeholders, including the public. The NNI should expand outreach and communication activities by the NNCO and the Nanotechnology Public Engagement and Communications Working Group and by coordinating existing agency communication efforts. To enhance effectiveness, the information should be developed with broad input and through processes that incorporate two-way communication with the intended audiences.

This review complements an assessment by the National Research Council (NRC) of the National Academies. The NNAP agrees with many of the NRC recommendations. However, the NNAP questions the recommendation for a formal, independent advisory panel. The panel feels that the current arrangement-whereby the NRC panels of technical experts, the high-level science and technology management leaders of PCAST, and the nanotechnology experts on the nTAG each provide distinct and useful input to the NNI review process—provides a broader perspective than would a single group consisting of a smaller number of advisors.

BIOGRAPHY FOR E. FLOYD KVAMME

E. Floyd Kvamme is a Partner Emeritus at Kleiner Perkins Caufield & Byers, a high-technology venture capital firm and, presently, serves on six high tech company boards including National Semiconductor, Harmonic, and Power Integrations. Since 2001, Kvamme has served as Co-Chair of President Bush's Council of Advisors in Science and Technology, (PCAST). He helped found National in 1967, serving as general manager of Semiconductor Operations. In 1982, he became Executive Vice President of Sales and Marketing for Apple Computer. He holds a BSEE from the University of California, Berkeley, and an MSE in semiconductor electronics from Syracuse University.

Chairman GORDON. Thank you. Mr. Murdock, you're recognized.

STATEMENT OF MR. SEAN MURDOCK, EXECUTIVE DIRECTOR, NANOBUSINESS ALLIANCE

Mr. MURDOCK. Thank you, Chairman Gordon. Chairman Gordon, Ranking Member Hall, and Members of the House Committee on Science and Technology, I would like to thank you for the opportunity to testify on the *National Nanotechnology Initiative Amendments Act of 2008.*

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the premier nanotechnology policy and commercialization advocacy group in the United States. Members span multiple stakeholder groups and traditional industrial sectors, including newly formed start-

ups, Fortune 500 companies, academic research institutions, and public-private partnerships working to derive economic development and growth through nanotechnology.

This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of quality-of-life improvements, economic growth, and business success in the 21st century. The Alliance provides a collective voice and a vehicle for efforts to advance the benefits of nanotechnology across our economy and society.

The NanoBusiness Alliance strongly supports the *National Nanotechnology Initiative Amendments Act of 2008* as drafted.

This committee has long recognized that nanotechnology is one of the most important frontiers of science and technology, and that nanotechnology has the potential to dramatically improve our quality of life, our health, our environment, and our economy. The National Nanotechnology Initiative, which this committee led Congress in authorizing in 2003, provided the framework for coordinated federal research and development. That authorization bill, the *21st Century Nanotech R&D Act,* focused on fundamental nanotechnology research.

Now, five years later, it is time to reauthorize and update this legislation. Much has changed in the past half-decade; nanotechnology is beginning to move from the laboratory to the store shelf.

American nanotechnology companies are beginning to shift from prototype development to large-scale manufacturing. Employers are beginning to look for nanotechnology-qualified workers. And the public is beginning to take notice of nanotechnology, with its many benefits and some potential risks, which need to be examined and managed.

That the landscape has changed so much in five years is in no small part due to the success of the National Nanotechnology Initiative itself. But its success at jump-starting the Nation's nanotechnology development means that the Initiative now needs to be updated to reflect five years of growth.

We are pleased that the Committee has thought carefully about how best to bring the National Nanotechnology Initiative up to date. The draft legislation will improve the Initiative's capabilities in several key areas, including translational research and development for commercialization, nanotechnology education, and environmental, health, and safety research.

As the Members of this committee know, America faces intense global competition in every field. But nowhere is this competition more intense than in the field of nanotechnology. Its economic development potential has led countries across Europe and Asia to make large and strategic investments in nanotechnology research and development. The stated goal of many of these countries is to dominate one or more sectors and change their geopolitical position. Russia has announced a $7 billion nanotechnology initiative that will spend nearly $750 million more on nanotechnology research each year than the United States. China is investing, on a purchasing power parity basis, approximately $1 billion and growing rapidly.

The United States continues to lead the world in fundamental nanotechnology research, but over the last five years we have seen our foreign competitors demonstrate that they are becoming equally capable of commercializing nanotechnology. We must reverse this trend. While we cannot and should not adopt our competitors' model of direct state investment in private companies, we can and should take steps to ensure that innovative American companies have unfettered access to American research and that they are able to commercialize that research efficiently and effectively. We should encourage programs such as the SBIR, the STTR program, and the Technology Innovation Program. We should focus our efforts on goal-oriented research in areas of national importance. And we should do everything we can to see that federal, state, and private resources are working together to bring these technologies to market.

The draft legislation does this. It retools the National Nanotechnology Initiative to focus more on applied research while maintaining a commitment to fundamental research. It supports large-scale collaborative efforts to develop nanotechnology solutions to key public policy challenges such as energy efficiency, environmental cleanup, and health care. And it updates the Initiative to include databases and other information-sharing mechanisms that actually help companies and the public understand what resources and opportunities to engage in are available.

The NanoBusiness Alliance is firmly committed to advancing nanotechnology education. We cannot expect to compete in the global economy if we are not generating nanotechnology-literate students who will go on to become leaders and workers in the nanotechnology economy of the future. We need to inspire American students to choose science tracks in high school and then provide them with hands-on nanotechnology opportunities in colleges and technical colleges.

As it stands, we are educating foreign students and then sending them home to compete against us. According to the NSF, foreign students on temporary visas earned 32 percent of all science and engineering doctorates awarded in the United States in the last year for which data is available. Foreign students earned 55 percent of engineering doctorates. Many of these students will ultimately return home. We must develop more domestic scientific talent if we are to lead in nanotechnology commercialization over the long haul. We believe that inspiration and inquiry-driven learning are key to accomplishing that.

The Alliance supports putting nanotechnology tools in the hands of students in community colleges and campuses so that they can see first-hand what nanotechnology is and why it is important. The Alliance also supports integrating local nanotechnology businesses into the program, and many of our members are already reaching out to schools to do that.

In terms of environmental health and safety research, nanotechnology has tremendous potential benefits for the environment, health and safety. But as we develop nanotechnology applications, we must do so responsibly, identifying and addressing any risks or hazards associated with nanotechnology before it causes environmental, health, or safety problems. The Alliance has called

for the National Nanotechnology Initiative to include a comprehensive, fully funded environmental, health, and safety research program, and this legislation does that.

The NanoBusiness Alliance believes that the environmental, health, and safety research should be fully funded and based on a clear, carefully-constructed research strategy. While we believe that 10 percent of the total funding for nanotechnology research and development is a reasonable estimate of the resources that will be required to execute the plan, we also believe that actual resource levels should be driven by the strategic plan, as they will vary significantly across agencies.

The Alliance appreciates the Committee's commitment to developing a broader understanding of nanotechnology before erecting an extensive new regulatory structure. We hope that Congress will see the wisdom of the Committee's approach and will use the research authorized by this bill as a basis for deciding what, if anything, is needed.

I would like to thank the Committee once again for the opportunity to testify and its leadership on this issue. Thank you very much.

[The prepared statement of Mr. Murdock follows:]

PREPARED STATEMENT OF SEAN MURDOCK

Chairman Gordon, Ranking Member Hall, and Members of the House Committee on Science and Technology, I would like to thank you for the opportunity to testify on the *National Nanotechnology Initiative Amendments Act of 2008*.

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the nanotechnology industry association and the premier nanotechnology policy and commercialization advocacy group in the United States.

NanoBusiness Alliance members span multiple stakeholder groups and traditional industrial sectors, including newly formed start-ups, Fortune 500 companies, academic research institutions, and public-private partnerships working to derive economic development and growth through nanotechnology.

This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of quality-of-life improvements, economic growth and business success in the 21st century. The Alliance provides a collective voice and a vehicle for efforts to advance the benefits of nanotechnology across our economy and society.

The NanoBusiness Alliance strongly supports the *National Nanotechnology Initiative Amendments Act of 2008* as drafted.

The Need for This Legislation

This committee has long recognized that nanotechnology is one of the most important frontiers of science and technology, and that nanotechnology has the potential to dramatically improve our quality of life, our health, our environment, and our economy. The National Nanotechnology Initiative, which this committee led Congress in authorizing in 2003, provided the framework for coordinated federal research and development. That authorization bill, the *21st Century Nanotechnology Research and Development Act,* focused on fundamental nanotechnology research.

Now, five years later, it is time to reauthorize and update this legislation. Much has changed in the past half-decade; nanotechnology is beginning to move from the laboratory to the store shelf. American nanotechnology companies are beginning to shift from prototype development to large-scale manufacturing. Employers are beginning to look for a nanotechnology-qualified workforce. And the public is beginning to notice nanotechnology, with its many benefits—and some potential risks, which need to be examined and managed.

That the nanotechnology landscape has changed so much in five years is in no small part due to the success of the National Nanotechnology Initiative. But its success at jump-starting the Nation's nanotechnology economy means that the Initiative now needs to be updated to reflect five years of growth.

We are pleased that the Committee has thought carefully about how best to bring the National Nanotechnology Initiative up to date. The draft legislation will improve the Initiative's capabilities in several key areas, including translational research and commercialization; nanotechnology education; and environmental, health, and safety research.

Translational Research and Commercialization

As the Members of this committee know, America faces intense global competition in every field. But nowhere is this competition more intense than in the field of nanotechnology. Nanotechnology's economic potential has led countries across Europe and Asia to make large strategic investments in nanotechnology research and development. The stated goal of many of these countries is to dominate one or more sectors of the nanotechnology economy. Russia has announced a $7 billion nanotechnology initiative that will spend nearly $750 million more on nanotechnology research each year than the United States will. China already is on par with the United States, when purchasing power is taken into account.

The United States continues to lead the world in fundamental nanotechnology research, but over the last five years we have seen our foreign competitors demonstrate that they are becoming equally capable of commercializing nanotechnology. By leveraging our research, these foreign governments and foreign companies are skipping the hard work and reaping the economic benefits.

We must reverse this trend. While we cannot and should not adopt our competitors' model of direct state investment in private companies, we can and should take steps to ensure that innovative American companies have unfettered access to American research, and that they are able to commercialize that research efficiently and effectively. We should encourage programs such as Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and the Technology Innovation Program (TIP). We should focus our efforts on goal-oriented research in areas of national importance. And we should do everything we can to see that federal, State, and private resources are working together toward the goal of bringing as much nanotechnology to market in the United States as possible.

The draft legislation does all of this. It retools the National Nanotechnology Initiative to focus more on goal oriented research, while maintaining a commitment to fundamental research. It gives the SBIR, STTR, and TIP programs a leading role. It supports large-scale collaborative efforts to develop nanotechnology solutions to key public policy challenges such as energy efficiency, environmental cleanup, and health care. And it updates the Initiative to include databases and other information-sharing mechanisms to help companies and researchers understand what resources are available.

Nanotechnology Education

The NanoBusiness Alliance is firmly committed to advancing nanotechnology education. We cannot expect to compete in the global economy if we are not generating nanotechnology-literate students who will go on to become leaders and workers in the nanotechnology economy. We need to inspire American students to choose science tracks in high school, and then provide them with hands-on nanotechnology opportunities in colleges and technical colleges.

As it stands, we are educating foreign students, and then sending them home to compete against us. According to the NSF, foreign students on temporary visas earned 32 percent of all science and engineering doctorates awarded in the United States in 2003, the last year for which data is available. Foreign students earned 55 percent of engineering doctorates. Many of these students expressed an intent to return to their country of origin after completing their studies.

The Alliance strongly supported the *Nanotechnology in the Schools Act,* and we are pleased to see that the current legislation reflects the goals of that bill. In particular, the Alliance supports putting nanotechnology tools in the hands of students, so that they can see first-hand what nanotechnology is and why it is important (and exciting). The Alliance also supports integrating local nanotechnology businesses into the program; many of our members are already reaching out to schools in their areas to help introduce students to nanotechnology.

Environmental, Health, and Safety Research

Nanotechnology has tremendous potential benefits for the environment, health, and safety (EHS). But as we develop nanotechnology applications, we must do so responsibly—identifying and addressing any risks or hazards associated with nanotechnology before they cause environmental, health, or safety problems. The Alliance has called for the National Nanotechnology Initiative to include a comprehen-

sive, fully funded environmental, health, and safety research program, and this legislation does just that. We strongly support this EHS research.

Americans need to know that the products they use are safe, or else they will not purchase or use them and the market for those products will collapse. The way to reassure consumers is not by ignoring any problems but by finding and dealing with any problems that may exist. A clear understanding of the environmental, health, and safety impacts of various kinds of nanoparticles is necessary, and that understanding must expand as new nanoparticles are developed.

The NanoBusiness Alliance believes that environmental, health, and safety research should be fully funded and based on a clear, carefully-constructed research strategy. While we believe that 10 percent of the total funding for nanotechnology research and development is a reasonable estimate of the resources that will be required to execute the strategic plan, we also believe that actual resource levels should be driven by the strategic plan as they will vary significantly across agencies.

The Alliance appreciates the Committee's commitment to developing a broader understanding of nanotechnology before erecting an extensive new regulatory structure. We hope that Congress will see the wisdom of the Committee's approach, and will use the research authorized by this bill as a basis for the decision of what, if any, new regulation is needed.

Conclusion

I would like to thank the Committee once again for the invitation to testify today, and for its leadership in working to ensure that America maintains its nanotechnology preeminence in the midst of intense global competition. The NanoBusiness Alliance commends this committee and its staff for the careful research and extensive collaboration that have led to this proposed legislation. We strongly support the *National Nanotechnology Initiative Amendments Act of 2008* as drafted.

BIOGRAPHY FOR SEAN MURDOCK

Sean Murdock is the Executive Director of the NanoBusiness Alliance, the nanotechnology industry association and the premier nanotechnology policy and commercialization advocacy group in the United States.

Prior to becoming the Executive Director of the NanoBusiness Alliance, Sean was the Executive Director and a founding board member of AtomWorks, an initiative formed to foster nanotechnology in Illinois and more broadly throughout the Midwest.

Sean has established himself as a leading thinker in the areas of nanotechnology commercialization and economic development. He has delivered keynote speeches on the commercialization of nanotechnology at nanotechnology conferences throughout the world. Sean has been quoted extensively on the subject in many leading publications including *Fortune, The Economist,* and the *New York Times.* He has also appeared on CNBC to discuss nanotechnology trends.

Sean has been very active in nanotechnology trade and economic development issues. He helped to organize and execute the first Nanotechnology Trade Mission to Europe in conjunction with the NanoBusiness Alliance and the U.S. Department of Commerce. He has also been engaged with senior officials of the U.S. Department of Commerce's Technology Administration on the potential impact of export control issues on nanotechnology development and commercialization.

Sean had more than seven years experience in management consulting, most recently as Engagement Manager at McKinsey & Company. Sean served a variety of Fortune 500 companies, focusing primarily upon the industrial and chemicals sectors. While there, he developed some of the firm's early perspective on the business opportunities created by the nanotech revolution, publishing the first two internal documents on the subject.

Sean received his Master's in Business Administration and Master's in Engineering Management from Northwestern University. He holds a BA in Economics from the University of Notre Dame.

Chairman GORDON. Thank you. Dr. Krajcik, you are recognized.

STATEMENT OF DR. JOSEPH S. KRAJCIK, PROFESSOR OF SCIENCE EDUCATION; ASSOCIATE DEAN OF RESEARCH, UNIVERSITY OF MICHIGAN

Dr. KRAJCIK. Chairman Gordon, Mr. Ehlers, and Members of the Committee, I am honored to present testimony on the *National Nanotechnology Initiative Amendments Act of 2008.* My name is Joe Krajcik, and I have been involved in science education for the last 34 years, first as a high school science teacher and now as professor of science education at the University of Michigan. I am currently co-PI in a National Science Foundation Center for Teaching and Learning in Nanoscale Science and Engineering; and because of this, I will speak primarily about the educational components of the Act.

Let me begin by stating that we live in a very exciting time with respect to advances in science and technology. We also live in a very exciting time with respect to education because we now know more about how people learn than ever before. The advances of nanoscale science and the global economy in which we live challenge the educational community to help all children develop deeper and more useful understanding of core science ideas that underlie nanoscience. Unfortunately, despite what we know about learning, the current education system is failing to produce a populace scientifically literate enough to understand the advances of nanoscience and to prepare a workforce for the new jobs and professions that are emerging from this field. Children in our country continue to lag behind in science and mathematics on international assessments. Perhaps most unfortunately, the most under-served children are in locations where typically children do not succeed in science: our nation's larger urban cities and rural areas.

As a nation, as we become more diverse, the challenge of how to provide quality science instruction is amplified. Our children will grow up in a world where they will need to apply and communicate scientific ideas, make sound decisions based upon this understanding, and collaborate with other people to solve important problems.

The *Nanotechnology Research and Development Act* provides important support to improve the education of children in this country. Although this is an important first step, I question whether this Act will provide sufficient resources to make a difference for all children. The advances in nanoscience requires a commensurate response from the educational community. As such, the financial resources needed to make this response possible must be provided by the national government with the private sector sharing in this responsibility.

To provide world-class science education so that all children learn ideas about nanoscience, our country needs to invest in several important initiatives. First, we need to invest in sustained professional development to support sixth through 12th grade teachers in learning content in the interdisciplinary way of thinking that is pervasive in nanoscience. Many teachers studied science when nanoscience ideas and the phenomena they explained had not emerged. Without providing teachers the opportunity to learn new content in this interdisciplinary way of thinking, they will not be able to instruct our children in these emerging science areas.

Sustained professional development is also needed to help teachers learn new pedagogical strategies and teaching techniques. We have learned much in the last 10 years about how to promote science learning. But unfortunately, many of these practices are not seen in science classrooms.

Second, our country needs to develop new standards and assessments that focus on the core ideas of science including those central to nanoscience. Although the National Science Education Standards moved this country forward in promoting standard-based reform, the standards are now at a stage for renovation, as they do not include ideas related to nanoscience and still cover too many ideas that prevent learners from developing useful understanding.

We also need to provide incentives to align all states in this country with this new shared vision of science teaching and learning.

Third, this country needs to develop new instructional resources including new learning technologies. Most instruction materials used in classrooms today do not include emerging science ideas and do not include the latest ideas about how children learn.

Fourth, we need to ensure that 6th through 12th grade science classrooms have appropriate equipment and facilities to allow all students to experience and explore doing science. When not feasible, partnerships with private sectors and universities need to provide this equipment.

Fifth, we need to redesign undergraduate education, including science teacher preparation programs, so that new ideas in science and learning and the interdisciplinary manner of thinking that nanoscience incorporates are included. It is only through revamping undergraduate education, including teacher preparation, that we will make lasting changes in science education. We need teachers who understand emerging ideas in science and the new ideas in teaching and learning. As such, we need to provide incentives to attract the very best science majors to teaching careers.

Finally, we need to build partnerships with the private sector in sharing in the cost of this effort.

In summary, to ensure all children in this country have access to world-class science education that will help them understand nanoscience and prepare them for fruitful lives in the future economy, we need to provide sustained professional development, renovate science education standards, develop and test new instructional materials, provide for appropriate equipment and resources, and redesign undergraduate education and build partnerships with the private sector.

Thank you for the opportunity to express my professional view.

[The prepared statement of Dr. Krajcik follows:]

PREPARED STATEMENT OF JOSEPH S. KRAJCIK

Dear Chairperson and Members of the Committee,

I am honored to present testimony on the *"National Nanotechnology Initiative Amendments Act of 2008."* My name is Joe Krajcik, and I have been involved in science education for the last 34 years, first as a high school science teacher and now as a Professor of Science Education. As a Professor of Science Education, I have focused my work on improving the teaching and learning of science at the middle

and high school levels. I am co-PI on an NSF-funded center, the National Center for Teaching and Learning in Nanoscale Science and Engineering, whose primary goal is to enhance the teaching and learning of nanoscience in grades 7–16 through learning research.

Let me begin by stating that we live in an exciting time with respect to the advances in science and technology, and that we know more about how people learn than ever before. Rapid advances in nanoscience have provided us with new products that have enhanced the quality of our lives ranging from diagnosing disease to improving the clothes we wear. At the same time, these new advances have also raised potential new dangers, because we have now created products that can penetrate the protective layer of skin that covers our bodies.

Nanoscale science and engineering are at the core of these changes and advancements. These new advances in nanoscience also have the potential to make the teaching of science more exciting and to build student engagement. Unfortunately, this promise has not been realized in most of our 7–12th grade science classrooms. These breakthroughs in science have brought new challenges to science teaching and learning. The advances of nanoscale science and the global economy in which we live challenge the educational community to help students develop deeper and more useful understanding of core science ideas that underlie nanoscience. Unfortunately, the current education system is failing to produce a populace scientifically literate enough to understand the scientific advances of nanoscience. It is also failing to prepare a workforce for the new jobs and professions that are emerging from nanoscience. Children in our country continue to lag behind in science and mathematics on international assessments; yet understanding science and mathematics is critical both for informed citizenship and for global competitiveness. To remedy these problems our country needs to invest in 1) professional development to support 6–12 science teachers in learning content related to nanoscience and new pedagogical ideas that are supported by learning research; 2) develop new standards and assessment that focus on the core ideas in science, including those central to nanoscience; 3) develop new instructional resources, including new learning technologies, that focus on nanoscience; 4) redesign undergraduate education, including science teacher preparation programs, so that new ideas in science and learning are incorporated into them; and 5) incentives to attract science majors and people who currently hold science majors into teaching careers.

We are also living in an exciting time because of the breakthroughs in understanding how to promote learning in science in general. Learning scientists and science educators are making important discoveries about ways to support learners in various aspects of inquiry, including the use of evidence and the construction of scientific explanations (Bransford, J.D., Brown, A.L., & Cocking, R.R., 1999; Duschl, Schweingruber, Shouse, 2007). The science standards on inquiry, described in the *National Science Education Standards* (1996) and the habits of mind articulated in *Benchmarks for Science Literacy* (American Association for the Advancement of Society, 1993), provide guidelines for how teachers should teach science. The science standards and benchmarks provide direction on the content ideas that children should know and the scientific practices they should be able to apply in order to be scientifically literate. New breakthroughs in technologies allow scientists and learners to explore the nanoworld and visualize data in new ways. Yet, even with these fascinating breakthroughs, many science classrooms in the United States still resemble classrooms of the early 1950s, with outdated equipment and pedagogical strategies that lack support for most learners. Perhaps most unfortunate, many of these classrooms are in locations where, typically, children do not succeed in science—our nation's large urban cities and rural areas. As our nation becomes even more diverse, with growing populations of Hispanics, African-Americans and other cultures, the challenge of how to provide quality science instruction is amplified. These children will grow up in a world where they will need to apply ideas, communicate ideas, make sound decisions based on evidence, and collaborate with others to solve important problems. Many of the new discoveries are in the area of nanoscience, and our children need to be prepared to enter this world. Yet most of our schools are not providing our students with the opportunities to develop the level of science understanding they will need to grasp emerging ideas of the nanoscale. Our science curriculum still concentrates on covering too much content without focusing enough on developing deep, meaningful understanding that learners will need to grasp these new areas or that they will need to make personal and professional decisions. Research has shown that students lack fundamental understanding of science in general and in particular the ideas that will help them understand nanoscience. What content should be taught? How should new ideas about nanoscience be introduced into 7–12 classrooms?

Through the *Nanotechnology Research and Development Act* (15 U.S.C. 7501(d)), the *National Nanotechnology Initiative Amendments Act of 2008* provides for the establishment of Nanoscience Education Partnerships. This Act will help provide important support to improve the education of all children in this country with respect to nanoscience education. The Act calls for 1) professional development activities to support secondary school teachers to use curricular materials incorporating nanotechnology and to inform teachers about career possibilities in nanotechnology; 2) enrichment activities for students, and 3) the identification of appropriate nanotechnology educational materials and incorporation of nanotechnology into the curriculum of schools participating in a Partnership. Although important first steps, I question whether this Act through the formation of Partnerships will provide sufficient resources that will make a difference for all children throughout the country. The advance in nanoscience requires a commensurate response from the educational community to prepare our youth. As such, the financial resources needed to make this response must be provided by the national government with help from the private sector. In particular, we need to ensure that all children in our country have access to first-rate science education that will help them understand the ideas of nanoscience and other emerging ideas.

The *Nanotechnology Research and Development Act* calls for providing support for professional development of teachers in nanotechnology. Yet, we need to make sure that this professional development is grounded in the science that teachers teach, focuses on teachers' practices and provides long-term, standards-based support (Garet, Porter, Desimone, Birman, & Yoon, 2001). The short-term professional development that most teacher experience will not provide enough or the type of support needed for most teachers to understand many of the new ideas and the changing ways of thinking about science at the nanoscale. The ideas of nanoscience were not in textbooks when many of our current teaching force attended college. As such, professional development will be needed that focuses on helping teachers understand the new ideas of nanoscience. Moreover, sustained professional development must provide science teachers support to use pedagogical strategies and techniques that will help students understand ideas behind nanoscience. One critical area that professional development needs to focus on is how to help teachers support students to generate, use, and evaluate evidence to create scientific explanations (Duschl, Schweingruber, Shouse, 2007). Another critical area includes support in using new learning technologies to engage students in visualizing the nanoworld; there are some good resources (see the Concord Consortium Web site, *Concord.org*, and the NCLT web site, *NCLT.US*) available to teachers already. Use of these new resources and instructional strategies will require sustained professional development.

Nanoscience is also an interdisciplinary field. Advances in science and technology are blurring the lines between the individual scientific disciplines. As science becomes more interdisciplinary, we can no longer rely on the traditional ways of teaching science as a set of well-understood, clearly depicted, stand-alone disciplines. However, how to teach in this fashion is not easy, particularly when teachers themselves did not experience education in this manner and pre-service programs preparing science teachers require science majors in specific science disciplines rather than providing interdisciplinary education. These present realities further the cycle of thinking within disciplines rather than between disciplines. We need to provide professional development and universities need to prepare teachers to teach in this interdisciplinary manner. Moreover, our nation needs to have learning research to support models of how to support teachers teaching in this manner.

Once teachers develop the content knowledge and pedagogical skills to teach nanoscience, they still will still face challenges teaching these new ideas to children unless they have appropriate classroom materials and resources. Some good instructional materials are beginning to appear, but more development and research is necessary to understand how they promote student learning. Although some teachers can develop curriculum materials, teachers modify curriculum to their local needs. If teachers can start with coherent materials that are known to promote learning, there is a great chance that students will learn important ideas (Kesidou, & Roseman, 2002).

Although the national science education standards in this country helped to bring about a focus on standards-based reform and coherent educational materials and assessments, the standards are now outdated and need revamping. New standards that focus on the big ideas of nanoscience (Stevens, Sutherland, Shank, & Krajcik, 2008) and other knowledge essential for the 21st century need to be developed and adapted by schools. Important ideas in nanoscience are not currently incorporated in the national standards. Nanoscience education introduces students to emerging ideas of science and supports understanding of the interconnections between the traditional scientific domains by providing compelling, real-world interdisciplinary ex-

amples of science in action. However, standards-based teaching with an interdisciplinary focus will also require extensive and sustained professional development.

The national science education standards also need renovation because there are too many standards. We know from successes in other countries and from research studies that attempting to cover too many ideas leads students to develop superficial knowledge that they cannot use to solve problems, make decisions, and understand phenomena. Hence, our national science education standards need reworking, updating and consolidating.

Renovating the standards is critical because assessments are driven by standards. If we develop standards that include the content understandings and scientific practices that we cherish for our children to develop, then more appropriate assessments will follow. Our current testing practices, however, put stress on classroom teachers, particularly when the testing practices do not align with important learning goals. Assessment, particularly assessment that challenges learners to use ideas and inform their development, is a good thing. We know that learners need to experience science in engaging contexts and apply ideas in order to learn; yet with so many standards, teachers feel as if they must cover topics in fear that students will not succeed on high stakes examinations rather than focus on helping students develop understanding. The national standards have allowed us to make headway in improving science instruction, but they still focus on too many content ideas and do not emphasis emerging ideas. Rather than focusing on covering too many ideas, our nation needs a long-term developmental approach to learning science that focuses on the ideas we most care about and takes into consideration learners' prior knowledge and how ideas build upon each other. The Act needs to include provisions that take into account this development and research work to develop new standards that can drive development of appropriate assessments, and new instructional materials and resources.

As our country now exists, each state has different standards, in addition to the national standards. This is not a workable system. We need to make certain that states buy into any new national standards and assessments by providing appropriate incentives. We need to find ways to ensure that states align themselves with these renovated national standards.

Learning nanoscience will not occur without appropriate resources for teaching these new ideas. The resources also need to include new laboratory equipment and technology equipment to teach nanoscience. Although the *Nanotechnology Research and Development Act* provides funds for course, curriculum and laboratory improvement for undergraduate education, the Act does not call for updating secondary science laboratories. The Act needs to provide support for improving secondary school science laboratory equipment. In order to learn science, students need to have essential firsthand experiences when possible and secondhand experiences to understand the complex ideas underlying nanoscience. Nanoscience cannot be taught and students will not develop understanding of the ideas underlying nanoscience without first- and secondhand experiences. Students need to experience and do science if they are going to learn with understanding. However, most U.S. high schools and middle school are ill-equipped for students to have these experiences. Budget cuts have caused schools to stop purchasing consumable science supplies and new materials, preventing students from experiencing phenomena. New laboratory equipment needs to allow learners to take part in inquiry experiences that will allow learners to put ideas together so that they can solve problems, make decisions, use and evaluate evidence, and explain phenomena.

The *Nanotechnology Research and Development Act* includes funds to revamp undergraduate education. Because of new content and the interdisciplinary nature of nanoscience, a revamping of how science is taught at the undergraduate level needs to occur. Lasting change, however, will only occur in K–12 education if support is provided to revamp how we prepare new teachers to teach emerging sciences such as nanoscience. We need to provide incentives to attract college students who have a deep understanding of the science into the teaching profession by providing new models of how they can enter certification programs. A major recommendation of the Glenn Report is that we need to find ways to attract science and mathematics undergraduates into the field of teaching and provide viable ways for them to learn how to teach and obtain certification. Preparing science teachers to teach in schools so that they can help all learners develop the level of understanding of science they need requires the revamping of undergraduate science and mathematics courses so that they reflect more what it is like to do science and mathematics as well as new models of how to prepare teachers. The Act needs to provide funds for both of these critical efforts. We will not change K–12 schools in the long run unless we change

undergraduate teacher education programs that better prepare teachers how to teach.

To summarize, schools face pressing challenges with respect to resources, assessment and professional development. Many teachers did not experience science in which ideas built upon each other in a developmental approach, where evidence was used to support claims and where science ideas were used to explain important problems and phenomena; as such, we need models of professional development and the resources that can support teachers as life long learners to learn new pedagogical strategies and new assessment practices. New ideas that emerge in science, such as nanoscience, also present challenges for teachers with respect to integration into curriculum.

For our children to live fruitful and fulfilled lives in an ever-globalizing world, our nation needs a system of science education that can prepare a scientifically literate population and a competent scientific workforce that has a useful understanding of the big ideas of science, including those of nanoscience. We are at a moment in history in which we, as a nation, need to provide learners with the scientific experiences, skills, and habits of mind that will allow them to make important decisions regarding the environment, their health, and our social policies. We have a growing body of knowledge that can help bring about this reform to science education.

We are at a crossroads in science education. We can continue to push and build upon the knowledge, resources and models of exemplary teachers who know how to engage students deeply to reform science education, or we can retreat to old pedagogical strategies that don't work. We need to build upon the strengths we have as a nation and resist yielding to testing pressures that focus on unimportant ideas and pedagogical strategies that we know do not work. Yet, we will only do so with leadership and support from our national government. We need funding to provide for and study the impacts of sustained professional development and the development of new science standards that take into consideration what we know about how children learn. We also need support to design curriculum resources and assessments that align with the new standards and to study the impact of these high quality resources on student learning. Finally we need support for the revamping of undergraduate education and developing new models of preparing teachers to teach. The *National Nanotechnology Initiative Amendments Act of 2008* provides some support for these important initiatives, but to provide the education that all children, regardless of their backgrounds and culture, need to live in a technology-driven world will require more support for improving teaching and learning.

I would like to thank you for the opportunity to present testimony to the House Committee on Science and Technology. I hope that you have found some of my remarks valuable.

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BIOGRAPHY FOR JOSEPH S. KRAJCIK

Joseph S. Krajcik, a Professor of Science Education and Associate Dean for Research in the School of Education at the University of Michigan, works with teachers in science classrooms to bring about sustained change by creating classroom environments in which students find solutions to important intellectual questions that subsume essential learning goals and use learning technologies as productivity tools. He seeks to discover the depth of student learning in such environments, as well as to explore and find solutions to challenges that teachers face in enacting such complex instruction. In collaboration with colleagues from Northwestern University, American Association of Science, and Michigan State, Joe, through funding from the NSF, is a principle investigator in a materials development project that aims to design, develop and test the next generation of middle school curriculum materials to engage students in obtaining deep understandings of science content and practices. Professor Krajcik has authored and co-authored over 100 manuscripts and makes frequent presentations at international, national and regional conferences that focus on his research as well as presentations that translate research findings into classroom practice. He is a fellow of the American Association for the Advancement of Science and served as President of the National Association for Research in Science Teaching in 1999. Joe co-directs the Center for Highly Interactive Classrooms, Curriculum and Computing in Education (hi-ce) at the University of Michigan and is a co-principle investigator in the Center for Curriculum Materials in Science and The National Center for Learning and Teaching Nanoscale Science and Engineering. In 2002, Professor Krajcik was honored to receive a Guest Professorship from Beijing Normal University in Beijing, China. In Winter 2005, Joe was the Weston Visiting Professor of Science Education at the Weizmann Institute of Science in Rehovot, Israel. Before obtaining his Ph.D. in Science Education, Joe taught high school chemistry for seven years in Milwaukee, Wisconsin. He received a Ph.D. in Science Education from the University of Iowa in 1986. His home page is located at: *http://www.umich.edu/~krajcik*. His project web sites include: *http://hice.org* and *http://hice.org/IQWST*.

Current Projects:

Longitudinal Student Outcomes in a Scaling Urban Inquiry-Based Science Intervention (Co-PI with Phyllis Blumenfeld). Spencer Foundation, $351,900, 7/1/2006 to 6/30/2008.

A Learning Progression for Scientific Modeling, PI, Brian J. Reiser, Co-PIs: Joseph S. Krajcik, Elizabeth Davis, Christina Schwarz, David Fortus. National Science Foundation, ESI–06281099, $1,738,829, October 1, 2006 to September 30, 2008.

Education for Community Genomic Awareness, from the National Institutes of Health (Co-PI with Toby Citrin from Public Health, #1 R25 RR022703–01, $1,341,329).

National Center for Teaching and Learning in Nanoscale Science and Engineering. National Science Foundation Center for Teaching and Learning (ESI–0426328), Co-PI (Robert Chang from Northwestern University, PI).

Collaborative Research: Developing the Next Generation of Middle School Science Materials—Investigating and Questioning our World through Science and Technology. National Science Foundation. Award Number—ESI–0439352. Krajcik, PI. Collaborative grant with Northwestern (Brian Resier)—five years for $6,267,023.

Chairman GORDON. Dr. Krajcik, I have some good news and bad news for you. The good news is that 99 percent of your recommendations were incorporated into a bill that we passed and the President signed last year called the *America COMPETES Act*. Amazingly, you recited the bill, basically. The bad news is that the tree doesn't fall if you don't hear it in that we have not been able to get the proper funding, or any funding really, for the bill yet. However, working with Dr. Ehlers, we are working in a bipartisan way to try to at least start that funding process. We have circulated a letter. Again, we have several Members on that. I see representatives from Texas Instruments here. They have been a part of bringing together I think 175 to 200 major industries and associations also recommending that the *America COMPETES Act*

gets funded. So hopefully at least the good news there is we have the authorization, and we are working very hard to try to get the funding for your almost exact recommendation.

Now, Dr. David, you and Dr. Ehlers, would you like to just say amen?

Dr. Maynard, you are recognized.

STATEMENT OF DR. ANDREW D. MAYNARD, CHIEF SCIENCE ADVISOR, PROJECT ON EMERGING NANOTECHNOLOGIES, WOODROW WILSON INTERNATIONAL CENTER FOR SCHOLARS

Dr. MAYNARD. Thank you very much. I would like to thank you, Chairman Gordon, Mr. Ehlers, and the Members of this committee for holding today's hearing. My name is Dr. Andrew Maynard. I am the Chief Science Advisor to the Project on Emerging Nanotechnologies which is a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts. But of course, the views I express here are my own.

Nanotechnology is counter-intuitive. It involves a world where materials just don't play by the rules as we know them but demonstrate many strange and wonderful behaviors. Metals change color, inert materials become highly reactive, what was once weak becomes strong. For instance, if you take a material like this, this is nanoscale titanium dioxide, it looks like a mundane, white powder. But this material's superfine structure which is invisible to the naked eye allows this particular material to be used to kill microbes, make self-cleaning windows, and ensure that mineral-based sunscreens go onto the skin transparently.

Because nanotechnology is counter-intuitive, safe nanotechnologies will not just happen. We will need leadership and guidance to help overcome our human scale perspective and ensure the rule book for safe nanotechnology is built on sound science.

In this context, I want to highlight five areas I believe are essential to underpinning the development of safe and therefore successful nanotechnologies.

First and foremost, I believe we need a top-level research strategy that identifies the goals of nanotechnology research across the Federal Government and provides a roadmap for achieving these goals.

Secondly, I strongly believe a minimum of 10 percent of the Federal Government's nanotechnology R&D budget should be dedicated to goal-oriented environmental, health, and safety research. Any less than this will risk compromising the success of emerging nanotechnologies.

Thirdly, a coordinator should be appointed with responsibility for overseeing and implementing a nanotechnology environmental, health, and safety research strategy across the government.

Fourthly, public-private partnerships are needed that leverage government and industry funds to address critical nanotechnology oversight issues in an independent, transparent, and timely manner.

And finally, government actions to support the development of safe nanotechnologies must be transparent. Without transparency,

there is no clear foundation for enabling strategic planning or engendering trust within industry or the public.

I think it is fair to say that transparency has been an issue for safety research so far within the NNI. Recently the National Nanotechnology Initiative announced that $68 million was spent on nanotech risk-related research in Fiscal Year 2006. But as has happened many times now, no clear supporting data were given for this figure.

Sifting through the research claiming to be relevant to nanotechnology safety, I could only find $13 million that was invested in research that is highly relevant to addressing the health and environmental impacts of nanotechnology for 2006. The same analysis, and this is somewhat interesting, for research in Europe over the same period reveals an investment of $24 million in nanotech safety research over the same period.

Unlike the NNI, the information that this analysis is based on is freely available on the web for anyone to see and anyone to verify. The bottom line here is that without supporting evidence, any assessment of what the government is doing to address nanotechnology impacts is quite simply not worth the paper it is written on.

Nanotechnology will not succeed through wishful thinking. Instead, it will depend on clear and authoritative leadership from the top. The proposed *National Nanotechnology Initiative Amendments Act of 2008* addresses each of the areas I have just highlighted and in my personal opinion supports the leadership necessary for the successful development of safe nanotechnologies.

I personally commend the Committee for promoting transparency through a public database of research. This will complement the International Public Database on Environmental, Health and Safety Research to be launched by the Organization for Economic Cooperation and Development in June of this year.

I also believe the proposed Act takes an important step in assigning to a single coordinator the responsibility for ensuring that an adequately funded and leveraged top-down strategic plan for nanotechnology EHS research is developed and implemented.

When I look back on the origins of the NNI, I am impressed by the foresight and quality of leadership exerted by the Congressional visionaries on both sides of the aisle, together with the President and the Executive Branch, scientists and engineers, business people, and educators. But perhaps because the tremendous success achieved in the laboratory since its creation, we do risk losing sight of the challenges involved in taking the NNI to the next level of research, education, governance, and commercialization. It is my belief that with the proposed Act and with a continued vigilance of this committee, this will not happen. Thank you.

[The prepared statement of Dr. Maynard follows:]

PREPARED STATEMENT OF ANDREW D. MAYNARD

Executive Summary

Nanotechnology has vast potential to address some of the greatest challenges facing society, including global climate change, poverty and disease. And with this potential comes the possibility of stimulating sustainable economic growth and job creation. The success of nanotechnology however is not a foregone conclusion. Alongside

the challenges of developing the underlying science are broader issues that will influence its success or failure:

– How can we learn to use such a powerful technology wisely?
– Who will decide how it is used, and who will pay the cost?
• How can innovative science be translated into successful products?
– And in an increasingly crowded and connected world, how will the supposed– beneficiaries of nanotechnology be engaged in its development and use?

These questions will not be answered without a clear strategy. And without vision and strong leadership, the future of safe and successful nanotechnologies will be put in jeopardy.

This committee should be applauded for having the foresight to author the *21st Century Nanotechnology Research and Development Act*—an Act that has enabled the United States to lead the world in developing research programs to unlock the potential of the nanoscale. Yet as nanotechnology has increasingly moved from the laboratory to the marketplace, the challenges have shifted from stimulating innovative research to using this research in the service of society. This is why it is so important that the *National Nanotechnology Initiative Amendment Act of 2008* builds on the strengths of the 2003 Act, and establishes a framework that will support nanotechnologies that can deliver on their promise. In particular, it is vital that the reauthorization addresses the potential for nanotechnologies to cause harm—and how this might be avoided.

Real and perceived risks that are poorly identified, assessed and managed will undermine even the most promising new technologies, and nanotechnology is no exception. In this context, the 2008 Act needs to explicitly address five areas if it is to establish a sound framework for enabling safe, sustainable and successful nanotechnologies:

1. **Risk Research Strategy.** A top-level strategic framework should be developed that identifies the goals of nanotechnology risk research across the Federal Government, and provides a roadmap for achieving these goals. The strategy should identify information needed to regulate and otherwise oversee the safe development and use of nanotechnologies; which agencies will take a lead in addressing specific research challenges; when critical information is needed; and how the research will be funded. This top-level, top-down strategy should reflect evolving oversight challenges. It should be informed by stakeholders from industry, academia and citizen communities. It should include measurable goals, and be reviewed every two years.
2. **Funding for environmental safety and health research.** A minimum of 10 percent of the Federal Government's nanotechnology research and development budget should be dedicated to goal-oriented environment, health and safety (EHS) research. At least $50 million per year should be directed towards targeted research directly addressing clearly-defined strategic challenges. The balance of funding should support exploratory research that is conducted within the scope of a strategic research program. Funding should be assessed according to a top-level, top-down risk research strategy, and be overseen by cross-agency leadership.
3. **Leadership for risk research.** A cross-agency group should be established that is responsible for implementing a nanotechnology EHS research strategy, and is accountable for actions taken and progress made. A coordinator should be appointed to oversee this group, as well as given resources and authority to enable funding allocations and interagency partnerships that will support the implementation of a strategic research plan.
4. **Transparency.** Government-funded nanotechnology environment safety and health research investment should be fully transparent, providing stakeholders with information on project activities, relevance, funding and outcomes.
5. **Public-Private Partnerships.** Partnerships that leverage public and private funds to address critical nanotechnology oversight issues in an independent, transparent and timely manner should be established, where such partnerships have the capacity to overcome the limitations of separate government and industry initiatives.

Nanotechnology is a truly revolutionary and transformative technology, and we cannot rely on past ways of doing things to succeed in the future. Without strong leadership from the top, we run the risk of compromising the whole enterprise—not

only losing America's technological lead, but also jeopardizing the good that could come out of nanotechnology for other countries and the world.

Already, the hubris surrounding nanotechnology research and development (R&D) funding is giving way to a sobering reality: Based on the federal National Nanotechnology Initiative (NNI)-identified risk-relevant projects, in 2006, the Federal Government spent an estimated $13 million on *highly relevant* nanotechnology risk research (approximately one percent of the nano R&D budget), compared to $24 million in Europe,[1] despite assurances from the NNI that five times this amount was spent on risk related research in Fiscal Year 2006.[2]

Nanotechnology will not succeed through wishful thinking alone. Instead, it will depend on clear and authoritative leadership from the top. If we are to fully realize the benefits of this innovative new technology, we must bridge the gap between our dreams and reality.

When I look back on the origins of the NNI, I am impressed by the foresight and quality of leadership exerted by Congressional visionaries from both sides of the aisle, the President and Executive Branch, scientists and engineers, business people, and educators.[3] Perhaps because of the tremendous successes achieved in the laboratory since its creation, we risk losing sight of the importance of meeting the challenges involved in taking the NNI to the next level of research, education, governance and commercialization. It is my belief that with the proposed Act—and with the continued vigilance of this committee—this will not happen.

Introduction

I would like to thank Chairman Bart Gordon, Ranking Republican Ralph Hall, and the Members of the House Committee on Science and Technology for holding this hearing on the *National Nanotechnology Initiative Amendments Act of 2008.*

My name is Dr. Andrew Maynard. I am Chief Science Advisor to the Project on Emerging Nanotechnologies (PEN) at the Woodrow Wilson International Center for Scholars. Through my research and other activities over the past 15 years, I have taken a lead in addressing how nanotechnologies might impact human health and the environment, and how we might realize the benefits of these exciting new technologies without leaving a legacy of harm. I was responsible for stimulating government research programs into the occupational health impact of nanomaterials in Britain towards the end of the 1990's. I spent five years developing and coordinating research programs at the Centers for Disease Control and Prevention's (CDC) National Institute for Occupational Safety and Health (NIOSH) that address the safety of nanotechnologies in the workplace. While at NIOSH, I represented the agency on the Nanoscale Science, Engineering and Technology (NSET) Subcommittee of the National Science and Technology Council (NSTC), and was Co-Chair of the Nanotechnology Environmental and Health Implications (NEHI) Working Group from its inception.

In my current role as Chief Science Advisor to PEN, I work closely with government, industry and other groups to find science-based solutions to the challenges of developing nanotechnologies safely and effectively. PEN is an initiative launched by the Woodrow Wilson International Center for Scholars and The Pew Charitable Trusts in 2005.[4] It is dedicated to helping business, government and the public anticipate and manage the possible health and environmental implications of nanotechnology. As part of the Wilson Center, PEN is a non-partisan, non-advocacy policy organization that works with researchers, government, industry, non-governmental organizations (NGOs), and others to find the best possible solutions to developing responsible, beneficial and acceptable nanotechnologies.

In this testimony, I will lay out essential components of an overarching framework to cultivate the growth and innovation of the emerging field of nanotechnology while providing safeguards for environmental, health and safety (EHS) and comment on the extent to which the current draft of the *National Nanotechnology Initiative Amendments Act of 2008* addresses these components.

The two aims of stimulating innovation and avoiding harm need not be, nor should be, mutually exclusive. A successful strategy of scientific and technological

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[1] These figures are based on an assessment of published U.S. and European risk-related research projects, and their relevance to addressing potential risks. See Annex A and Annex B for further information. Full access to the information used in the assessment is available at *www.nanotechproject.org/inventories/ehs/* (accessed 4/15/08).

[2] NNI (2008). Strategy for nanotechnology-related environmental, health and safety research, National Nanotechnology Initiative, Washington DC.

[3] Lane, Neal and Kalil, Thomas, "The National Nanotechnology Initiative: Present at the Creation," *Issues in Science and Technology,* Summer 2005.

[4] For further information see *www.nanotechproject.org.* Accessed April 4, 2008.

innovation, integrated with EHS research, will ensure that the promised benefits of such a technology are not thwarted by potential EHS disasters. With nanotechnology, we have the opportunity to do things differently. It is my belief that the proposed reauthorization of the National Nanotechnology Initiative (NNI) will redefine how emerging technologies are developed successfully and safely.

Underpinning Sustainable Nanotechnologies

The promise of nanotechnology

Nanotechnology has the potential to revolutionize the world as we know it. The increasing dexterity at the nanoscale provides opportunities to greatly enhance existing technologies and to develop innovative new technologies. When you couple this capability with the unusual and sometimes unique behavior of materials that are engineered at near-atomic scales, you have the basis for a transformative technology that has the potential to impact virtually every aspect of daily life. Some of these emerging technologies will benefit individuals, while others will help solve pressing societal challenges like climate change, access to clean water and cancer treatment. And many will provide companies with the competitive edge they need to succeed. In all cases, nanotechnology holds within it the potential to improve the quality of life and economic success of America and the world beyond.

Unconventional behavior

The benefits of nanotechnology, however, will not be realized by default. Nanotechnology is taking our understanding of what makes something harmful and how we deal with that, and turning it upside down. New engineered nanomaterials are prized for their unconventional properties. But these same properties may also lead to new ways of causing harm to people and the environment.[5] Research has already demonstrated that some engineered nanomaterials can reach places in the body and the environment that are usually inaccessible to conventional materials, raising the possibility of unanticipated harm arising from unexpected exposures. And studies have shown that the toxicity of engineered nanomaterials is not always predictable from conventional knowledge.[6] For instance, we now know that nanometer sized particles can move along nerve cells; that the high fraction of atoms on the surface of nanomaterials can influence their toxicity; and that nanometer-diameter particles can initiate protein mis-folding, possibly leading to diseases.

The need for foresight

Moving towards the nanotechnology future without a clear understanding of the possible risks, and how to manage them, is like driving blindfolded. The more we are able to see where the bends in the road occur, the better we will be able to navigate around them to realize safe, sustainable and successful nanotechnology applications. But to see and navigate the bends requires the foresight provided by strategic science.

With over 600 products currently listed on the PEN's Consumer Products Inventory[7] and with hundreds more commercial nanotechnology applications on the market or under development, the question is no longer *whether* nanotechnologies will impact society but *how significant* the impact will be. The question for policy-makers is *how* these impacts will be manifest, and how we will manage the consequences.

Avoiding harm

Central to developing sustainable nanotechnologies is an understanding of how new materials and products may harm people and the environment, and how possible risks may be avoided or otherwise managed.

Everything has the potential to cause harm. If we are smart, we learn how to avoid harm. And if we are very smart, we work out the rules of safe use ahead of the game. In a world of more than six billion people, everything that occurs has an

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[5] Maynard, A.D., Aitken, R.J., Butz, T., Colvin, V., Donaldson, K., Oberdorster, G., Philbert, M.A., Ryan, J., Seaton, A., Stone, V., Tinkle, S.S., Tran, L., Walker, N.J. and Warheit, D.B. (2006). Safe handling of nanotechnology. *Nature* 444:267–269.

[6] Oberdbrster, G., Stone, V. and Donaldson, K. (2007). Toxicology of nanoparticles: A historical perspective. *Nanotoxicology* 1:2–25.

[7] An inventory of nanotechnology-based consumer products currently on the market. *http://www.nanotechproject.org/inventories/consumer/*. Accessed 3/30/08.

impact on some place and someone. And as a result, each emerging technology forces us to think harder about what the consequences might be, and how to avoid them.

Ignoring the signs of adverse consequences will only result in poor decision-making by governments, business and individuals. While nanotechnology undoubtedly has the potential to do great good, the consequences of getting it wrong could be devastating. Already, research is indicating that many nanomaterials behave in unusual and unconventional ways that may lead to human and environmental harm if not addressed early on.

A new mindset for a new technology

Twenty-first century technologies like nanotechnology present new challenges to identifying and managing risks, and it would be naive to assume that twentieth century assumptions and approaches are up to the task of protecting health and the environment in all cases. In the case of engineered nanomaterials, the importance of physical structure in addition to chemical composition in determining behavior is making a mockery of our chemicals-based view of risks and regulation.

As a simple example, imagine picking up two common kitchen implements—a skillet and a knife. Each can be used for very different purposes—for instance, the knife for slicing an onion and the skillet for frying it. Likewise, each implement can cause harm in different ways. Yet the chemical makeup of each implement is very similar—it is predominantly iron. The very different rules for safe use are intuitive, because one can see how the different shapes of the implements influence behavior.

Nanomaterials are the same, in that how they behave—for good or bad—depends on their shape as well as their chemistry. But this is where nanotechnology becomes counter-intuitive. Because we cannot see these intricate nano-shapes unaided, we forget that they are important. If one were to hold up ajar of nanometer-sized titanium dioxide particles all that would be seen is a white powder, indistinguishable from many other powdered materials. Yet the potential for this material to be used in new applications, and possibly to cause harm in new ways, lies within the nanoscale structure of the material that can only be seen using advanced microscopy techniques.

Leadership

In thinking through how the potential risks of nanotechnologies can be proactively addressed and the technologies can be developed safely, some things are clear. Safe nanotechnologies will not happen without help—nanotechnologies are simply too unconventional and counter-intuitive. Neither will safe nanotechnologies emerge if the promoters of the technology are calling all the shots. And in a similar vein, safe nanotechnologies will not come about through wishful thinking and "spin."

Instead, there needs to be strong independent leadership, and a framework within which safe and sustainable nanotechnology can be developed. These must ensure adequately funded research is targeted towards understanding and addressing counter-intuitive behavior, that the process of developing safe and sustainable nanotechnologies is transparent and inclusive, and that activities are coordinated and directed towards developing solutions to developing and using nanotechnologies as safely as possible.

Only then will it be possible to develop the foresight necessary to ensure emerging nanotechnologies are as safe and as useful as possible. Having set the pace of nanotechnology development in the U.S. through the *21st Century Nanotechnology Research and Development Act,* the House Committee on Science and Technology now has the task of ensuring these emerging nanotechnologies deliver on their promise; benefiting society without causing harm.

Taking Action

Risk Research Strategy

We are unlikely to arrive at a future where nanotechnology has been developed responsibly without a strategic plan for how to get there. Like all good strategies, this should include a clear idea of where we want to be, and what needs to be done to get there. A top-level, top-down strategic framework should be developed that identifies the goals of nanotechnology risk research across the Federal Government, and that provides a roadmap for achieving these goals. The strategy should identify information needed to regulate and otherwise oversee the safe development and use of nanotechnologies; which agencies will take a lead in addressing specific research challenges; when critical information is needed; and how the research will be fund-

ed. It should reflect evolving oversight challenges; be informed by stakeholders from industry; academia and citizen communities; include measurable goals; and be reviewed every two years.

Developing an effective roadmap to addressing these challenges is not as simple as prioritizing research needs. As I discovered while developing recommendations on research strategies in 2006,[8] it is necessary to work back from what you want to achieve, and map out the research steps needed to get there. This inevitably leads to complex and intertwined research threads. Yet if this complexity is not acknowledged, the result is simplistic research priorities that look good on paper, but are ineffective at addressing specific aims. And without a clear sense of context, it is all too easy to highlight research efforts that appear to be strategically important, but are in reality only marginal to achieving the desired goals.

The bottom line is that for such a strategy to be effective, it will require top-down leadership. Establishing provisions for an effective nanotechnology risk research strategy to be developed, funded and implemented in the *National Nanotechnology Initiative Amendment Act of 2008* will be essential to underpinning the success and safety of current and future nanotechnologies, as well as ensuring America's continued leadership in this area.

Funding for Environment, Safety and Health Research

To be effective, a nanotechnology risk-research strategic framework needs adequate funding to support proposed research, as well as sufficient expert personnel to oversee its development and implementation. In 2006, the U.S. spent an estimated $13 million on highly relevant research addressing the impacts of nanotechnology on human health and the environment.[9] By comparison, European countries invested approximately $24 million, including $13 million from the European Union as a central funding organization. But these figures fall far short of what is needed to address even the most urgent nanotechnology EHS questions.

In my testimony to this committee on September 21, 2006,[10] and more recently on October 31, 2007,[11] I made the case for a minimum of $50 million annually to be spent on targeted nanotechnology risk research within the U.S. This was based on an assessment of critical short-term research needs, and only covered highly-focused research to address these needs.[12] This estimate still stands. However, I must be clear that such an investment would need to be directed towards addressing a very specific suite of problems that regulators and industry need answers to as soon as possible. This is not envisaged as a general pot of money to be assigned to research that does not address specific and urgent nanotechnology risk goals. In other words, this is an investment that needs to be directed towards the right research.

What is more, such an investment would not necessarily generate more general knowledge to effectively address emerging nanotechnology EHS issues. For this, an additional investment is needed in goal-oriented exploratory research—both specifically focusing on aspects of nanotechnology that might lead to harm, and bridging the worlds of applications and implications research.

To address both targeted and exploratory research needs, a *minimum* 10 percent of the Federal Government's nanotechnology research and development budget should be dedicated to goal-oriented EHS research. A minimum of $50 annually should go to targeted research directly addressing clearly-defined strategic challenges. The balance of funding should support exploratory research that is conducted within the scope of a strategic research program. Funding should be assessed according to an interagency risk research strategy, be overseen by cross-agency leadership and tied into the strategic research plan.

Targeted research primarily should address specific questions where answers are urgently needed to make, use and dispose of nanotechnology products as safely as possible. I would envisage that much of the necessary research would be funded by or conducted within mission-driven agencies, such as the National Institute for Oc-

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[8] Maynard, A.D. (2006). *Nanotechnology: A research strategy for addressing risk,* Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington DC.

[9] See Annex A, and supporting information in Annex B.

[10] United States House of Representatives Committee on Science. Hearing on Research on *Environmental and Safety Impacts of Nanotechnology: What are Federal Agencies Doing?* Testimony of Andrew D. Maynard. September 21, 2006.

[11] United States House of Representatives Committee on Science. Hearing on *Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation Under the National Nanotechnology Initiative.* Testimony of Andrew D. Maynard. October 31, 2007.

[12] See also: Maynard, A.D. (2006). *Nanotechnology: A research strategy for addressing risk,* Woodrow Wilson International Center for Scholars, Project on Emerging Nanotechnologies, Washington, DC.

cupational Safety and Health (NIOSH) and the Environmental Protection Agency (EPA). In addition, we must ensure that regulatory agencies, including the Food and Drug Administration (FDA) and the Consumer Product Safety Commission (CPSC), either have access to resources to fund regulation-relevant research, or input to research that will inform their decision-making.

There will also be a role for science-oriented agencies such as the National Institutes for Health (NIH) and the National Science Foundation (NSF) in funding targeted research, where the missions of these agencies coincide with research that informs specific oversight questions. For example, these two agencies are ideally positioned to investigate the science behind nanomaterial properties, behavior and biological interactions in a targeted way, with the aim of predicting health and environmental impact. But ensuring that targeted research conducted within these agencies is relevant to addressing risk identification, assessment and reduction goals will be critical, and underscores the need for a robust cross-agency, risk-research strategy and pool of designated funds.

Exploratory research, on the other hand, primarily would be investigator-driven (within determined bounds), and so would preferentially lie within the remit of NSF and NIH. However, in ensuring effective use of funds, it will be necessary to develop ways of supporting interdisciplinary research that crosses the boundary separating these agencies, and combines investigations of basic science with research into disease and environmental endpoints, with the goal of informing oversight decisions.

Exploratory research should not be confined to these two agencies alone, as there will be instances where goal-oriented but exploratory research will fit best within the scope of mission-driven agencies, and will benefit from research expertise within these agencies. For example, researchers at NIOSH are currently engaged in exploratory research that is directly relevant to identifying and reducing potential nanotechnology risks in the workplace.[13]

At present, there is no pot of "nanotechnology" money within the Federal Government that can be directed to areas of need. Rather, the NNI simply reports what individual agencies are spending. Yet if strategic nanotechnology risk research is to be funded appropriately, mechanisms are required that enable dollars to flow from where they are plentiful to where they are needed. Extremely overstretched agencies like NIOSH and EPA cannot be expected to shoulder their burden of nanotechnology risk-research unaided, and agencies such as FDA and CPSC currently have no listed budget whatsoever for nanotechnology EHS research. If the Federal Government is to fully utilize expertise across agencies and enable effective nanotechnology oversight, resource-sharing across the NNI will be necessary.

Leadership for Risk Research

Without clear leadership, the emergence of safe nanotechnologies will be a happy accident rather than a foregone conclusion.

This is a collection of technologies that is counter-intuitive and as a result, safe and sustainable nanotechnologies will not emerge without help. Accepted mechanisms of technology development and transfer—including investigator-driven research, generation of intellectual property, knowledge diffusion and market-driven commercialization—will not ensure the information and approaches needed to proactively ensure the safety of emerging nanotechnologies on their own. Instead, clear and authoritative top-down leadership is needed to enable the generation and application of information that will support safe nanotechnology development.

As a result, it is recommended that a cross-agency group be established that is responsible for implementing a nanotechnology EHS research strategy, and is accountable for actions taken and progress made. A coordinator should be appointed to oversee this group, and given resources and authority to enable funding allocations and interagency partnerships that will support the implementation of a strategic research plan. A key role for this coordinator would be to ensure agencies are motivated and able to work within their missions and competencies toward a common set of established goals. They would also provide leadership to the broader stakeholder community involved—both nationally and internationally—in developing safe nanotechnologies.

Transparency

Without transparency, effective development, implementation and review of a strategic research framework will be hampered, stakeholder engagement will be im-

[13] NIOSH (2008). Strategic plan for NIOSH nanotechnology research. Filling the knowledge gaps. Draft, February 26, 2008 (Update). National Institute for Occupational Safety and Health, Washington, DC.

possible, and trust in the government to underpin safe nanotechnologies will be severely compromised. As a result, it is recommended that government-funded nanotechnology EHS research should be fully transparent, providing stakeholders with information on project activities, relevance, funding and outcomes.

Activities to date within the federal nanotechnology initiative have been less than transparent, to the detriment of an effective strategy for nanotechnology development and use. For example, a PEN analysis of current research projects listed in the National Nanotechnology Initiative's "Strategy for Nanotechnology-Related Environmental, Health, and Safety Research" found that only 62 of the 246 projects listed were highly relevant to addressing EHS issues (the remaining projects had some relevance, but in general were focused on exploiting nanotechnology applications).[14] These 62 projects accounted for an estimated $13 million in research and development funding for 2006—a far cry from the $68 million cited by the NNI document as being focused on EHS research.[15] Each of these 246 projects has some relevance to addressing nanotechnology safety, and the NNI was right to list them. But by not categorizing the relevance of the research or including funding figures for each project, the stated $68 million being invested has little credibility—and as has just been shown, is indeed highly misleading.

Lack of transparency such as this can only hinder the development of new knowledge that is essential to ensuring safe and successful nanotechnologies. This is such a critical issue to underpinning progress towards safe and successful nanotechnologies that I would suggest any assessment of research investment, relevance or direction that is *not backed up by publicly accessible project-specific data* is worthless. It is for this very reason that the Organization for Economic Cooperation and Development (OECD) Working Party on Manufactured Nanomaterials is developing a soon-to-be-launched comprehensive database on risk-relevant nanotechnology research around the world.[16]

Public-Private Partnerships

Often, partnerships between public and private organizations have the capacity to address critical challenges in a manner that is beyond the scope of either partner in isolation. To expedite progress towards ensuring the safety of emerging nanotechnologies, it is recommended that partnerships are established that leverage public and private funds to address critical nanotechnology oversight issues in an independent, transparent and timely manner and to overcome the limitations of separate government and industry research.

Where research needs fall between the gap of government and industry (because of their different goals), public-private research partnerships provide an important mechanism for bridging the gaps. Industries investing in nanotechnology have a financial stake in preventing harm, manufacturing safe products and avoiding long-term liabilities. Yet many of the questions that need answering are too general to be dealt with easily by industry alone. Perhaps more significantly, the credibility of industry-driven risk research is often brought into question by the public and NGOs as not being sufficiently independent and transparent. For many nanomaterials and nanotechnologies, the current state of knowledge is sufficient to cast doubt on their safety but lacks the certainty and credibility for industry to plan a clear course of action on how to mitigate potential risks. Getting out of this "information trap" is a dilemma facing large and small nanotechnology industries alike.

Cooperative science organizations like public-private partnerships provide one way out of the "trap" where they are established to generate independent, credible data that will support nanotechnology oversight and product stewardship. Such organizations would leverage federal and industry funding to support targeted re-

[14] See Annex A, with supporting information in Annex B. Project specific data underpinning this analysis can be found in the Project on Emerging Nanotechnologies Environment, Health and Safety Research inventory (*http://www.nanotechproject.org/inventories/ehs/*, accessed 4/15/08). This inventory is in the process of being adopted and updated by the Organization for Economic Cooperation and Development, Working Party on Manufactured Nanomaterials.

[15] Further independent assessment of research funded in 2006 reveals funding for highly relevant risk research was closer to $20 million (*http://www.nanotechproject.org/inventories/ehs,* accessed 4/8/08). The discrepancy appears to be due to relevant research that the NNI missed in their analysis—another indicator that the government is not on top of what research is being funded, and lacks sufficient transparency for effective accountability.

[16] The OECD nanotechnology risk research database is based on the Project on Emerging Nanotechnologies inventory of nanotechnology Environment, Health and Safety Research (*http://www.nanotechproject.org/inventories/ehs/*, accessed 4/8/08). Due to be launched in June 2008, it will include information on project relevance to addressing nanotechnology risks, and funding levels. For further details, see *http://www.oecd.org/dataoecd/34/6/37852382.ppt* (accessed 4/8/08).

search into assessing and managing potential nanotechnology risks. Their success would depend on five key attributes:

Independence. The selection, direction and evaluation of funded research would have to be science-based and fully independent of the business and views of partners in the organization.

Transparency. The research, reviews and the operations of the organization should be fully open to public scrutiny.

Review. Research supported by the organization should be independently and transparently reviewed.

Communication. Research results should be made publicly accessible and fully and effectively communicated to all relevant parties.

Relevance. Funded research should have broad relevance to managing the potential risks of nanotechnologies through regulation, product stewardship and other mechanisms.

As I discussed in my comments to the House Committee on Science and Technology Subcommittee on Research and Science Education last October,[17] a number of research organizations have been established over the years that comply with many of these criteria. One of these is the Health Effects Institute (HEI),[18] which has been highly successful in providing high-quality, impartial, and relevant science around the issue of air pollution and its health impacts. The Foundation for the National Institutes for Health[19] also has been successful in developing effective public-private partnerships, and the International Council on Nanotechnology (ICON)[20] is a third model for bringing government, industry and other stakeholders to the table to address common goals. The PEN is currently exploring these and other models as possible templates for public-private partnerships addressing nanotechnology risks.

Irrespective of which model is the best suited for nanotechnology, the need is urgent to develop such partnerships as part of the government's strategy to address nanotechnology risks. Nanotechnologies are being commercialized rapidly—going from $60 billion in manufactured goods in 2007 to a projected $2.6 trillion in nanotechnology-enabled manufactured goods by 2014—or 15 percent of total manufactured goods globally.[21] And knowledge about possible risks is simply not keeping pace with consumer and industrial applications.

Conclusions

The nanotechnology future is calling us forward, and the U.S. is at the forefront of the race to get there as fast as possible. But we are skating on thin ice, and are in danger of missing the warning signs. Nanotechnology is counter-intuitive, and we cannot rely on past ways of doing things to succeed in the future. Without strong leadership from the top, we run the risk of compromising the whole enterprise—not only loosing America's lead, but also jeopardizing the good that could come out of nanotechnology for other countries.

Already, the hubris surrounding nanotechnology R&D funding is giving way to a sobering reality: Based on NNI-identified risk-relevant projects, in 2006, the Federal Government spent an estimated $13 million on *highly relevant* nanotechnology risk research (approximately one percent of the nano R&D budget), compared to $24 million in Europe, despite assurances from the NNI that five times this amount was spent on risk related research in Fiscal Year 2006.

But nanotechnology will not succeed through wishful thinking alone. Instead, it will depend on clear and authoritative leadership from the top. If we are to fully realize the benefits of this innovative new technology, we must bridge the gap between our dreams and reality.

[17] United States House of Representatives Committee on Science, Subcommittee on Research and Science Education. *Research on Environmental and Safety Impacts of Nanotechnology: Current Status of Planning and Implementation Under the National Nanotechnology Initiative.* Testimony of Andrew D. Maynard. October 31 2007.

[18] For further information see The Health Effects Institute, *www.healtheffects.org.* Accessed Oct. 13, 2007.

[19] For further information see The Foundation for the National Institutes of Health, *www.fnih.org.* Accessed Oct. 13, 2007.

[20] For further information, see the International Council on Nanotechnology, *icon.rice.edu.* Accessed Oct. 13, 2007.

[21] Lux Research (2007). *The Nanotech Report.* 5th edition, Lux Research Inc., New York, N.Y.

In my personal view, the proposed *National Nanotechnology Initiative Amendment Act of 2008* goes a long way to bridging this gap. I particularly commend the Committee for promoting transparency through a public database for projects funding under EHS; education and societal dimensions; and nanomanufacturing program component areas, with sub-breakouts for education and ethical, legal and social implications (ELSI) projects. This database will complement the public international EHS database expected to be launched by the Organization for Economic Cooperation and Development (OECD) in June 2008, and will provide an essential resource for evaluating the Federal Government's progress towards addressing critical research questions, as well as developing future research strategies.

In addition, I believe the proposed act takes an important step in assigning to a single coordinator the responsibility for ensuring that a top-down strategic plan for nanotechnology environmental, safety and health research is developed and implemented; that EHS research is appropriately funded with *at least* 10 percent of the total NNI budget; and that public-private partnerships are established that leverage government and industry research initiatives.

Finally, as the Committee knows, my in-depth experience lies in the area of the EHS implications of nanotechnology. But as one of the many scientists and engineers deeply involved in nanotechnology development for over 20 years, I am genuinely concerned about the education and "nano-readiness" of America's students, teachers, and workforce. For this reason, I personally endorse the establishment of partnerships to help recruit and prepare secondary school students to pursue post-secondary education in nanotechnology. I also support enhancements to nanotechnology undergraduate education, faculty development, and acquisition of equipment and instrumentation at the undergraduate level. When today China has as many scientists and engineers working on nanotechnology as the U.S., it is critical to support initiatives in nanotechnology education aimed at our young people.

Similarly, the U.S. public and consumers are woefully unprepared for the nanoage. Polling, focus groups and social science research commissioned by PEN since its inception show that Americans' awareness of nanotechnology remains abysmally low, with seven in 10 adults having heard just a little of nothing at all about it.[22] This, in my opinion, is a significant failing of the NNI. Too few resources and too little expertise has been devoted to educating and engaging the public about the implications of what I believe is one of this century's most exciting areas of science and engineering. I particularly urge the Committee to address this problem as it works on the *National Nanotechnology Initiative Amendment Act of 2008*.

When I look back on the origins of the National Nanotechnology Initiative, I am impressed by the foresight and quality of leadership exerted by Congressional visionaries from both sides of the aisle, the President and Executive Branch, scientists and engineers, business people, and educators.[23] Perhaps because of the tremendous successes achieved in the laboratory since its creation, we risk losing sight of the importance of meeting the challenges involved in taking the NNI to the next level of research, education, governance and commercialization. It is my belief that with the proposed Act—and with the continued vigilance of this committee—this will not happen.

[22] "Awareness Of and Attitudes Toward Nanotechnology and Federal Regulatory Agencies" conducted on behalf of the Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars by Peter D. Hart Research Associates, Inc., September 25, 2007.

[23] Lane, Neal and Kalil, Thomas, "The National Nanotechnology Initiative: Present at the Creation," *Issues in Science and Technology,* Summer 2005.

Annex A.

Assessment of U.S. Government Nanotechnology Environmental Safety and Health Research for 2006

1. Assessment of research listed in the 2008 NNI nanotechnology risk research strategy.[24]

a. Research projects **highly relevant** to nanotechnology environment health and safety accounted for an estimated **$12.8 million** in federal research funding in 2006.

b. Research that was either **highly or substantially** relevant to nanotechnology EHS accounted for an estimated **$28.9 million.**

c. The majority of the research projects listed by the NNI as being relevant to nanotechnology EHS have only limited relevance.

Listed research was categorized according to its relevance to addressing potential nanotechnology risks (highly relevant, substantially relevant, having some relevance, or having marginal relevance—as defined below). Projects specifically addressing engineered nanomaterials, as well as projects generally applicable to any source of nanoparticles, were included in the analysis.

The methodology for categorizing research relevance was the same as that used in the Project on Emerging Nanotechnologies on-line inventory of nanotechnology EHS research,[25] and in the forthcoming OECD database of nanotechnology EHS research.[26] This approach allows a sophisticated and transparent assessment of research investment. The categorization is based on published project abstracts, and how these relate to addressing risk-specific issues.

2. A broader assessment of U.S. federally-funded risk-relevant research for 2006

The previously-released PEN inventory of EHS research contains substantially more projects than are listed in the 2008 NNI risk research strategy. Assessment of the full inventory of projects reveals that more risk-relevant research was being funded in 2006 than is identified by the NNI, but that funding levels are still low:

a. Research projects **highly relevant** to nanotechnology environment health and safety accounted for an estimated **$20.4 million** in federal research funding in 2006.

b. Research that was either **highly or substantially** relevant to nanotechnology EHS accounted for an estimated **$37.8 million.**

The disparity between the figures above and NNI figures on research spending underline an urgent need for transparency in what is being funded, and it's relevance to addressing nanotechnology risk.

3. Comparison with European Risk Research Investments

a. In 2006, European countries invested an estimated **U.S. $23.6 million** in research that was highly relevant to understanding and addressing the impacts of nanotechnology on human health and the environment. The EU as a central funding organization invested an estimated U.S. $12.6 million in highly relevant research in 2006.

These estimates are based on figures published in the document "EU nanotechnology R&D in the field of health and environmental impact of nanoparticles," published in 2008.[27] Research funding within European countries for calendar year 2006 has been estimated. The analysis includes research funded by the European Union, Belgium, Czech Republic, Denmark, Finland, Germany, Greece, Sweden, Switzerland and the United Kingdom.

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[24] NNI (2008). Strategy for nanotechnology-related environmental, health and safety research, Washington, DC, National Nanotechnology Initiative.

[25] Environment, safety and health research. *www.nanotechproject.org/inventories/ehs/* (accessed 4/15/08).

[26] For further details on the OECD risk research database, see *http://www.oecd.org/dataoecd/34/6/37852382.ppt* (accessed 4/8/08).

[27] EU nanotechnology R&D in the field of health and environmental impact of nanoparticles. DG Research, January 28, 2008.

4. Definitions of research relevance:

a. **High:** Research that is specifically and explicitly focused on the health, environmental and/or safety implications of nanotechnology. Also included in this category are projects and programs where the majority of the research undertaken is specifically and explicitly focused on the health, environmental and/or safety implications of nanotechnology. Examples of research in this category would include research to understand the toxicity of specific nanomaterials, research into exposure monitoring and characterization to further understand potential impact, research into biological interactions and mechanisms that is focused on answering specific questions associated with potential risk. Examples of research that would not be included in this category would include exploratory research into biological mechanisms outside the context of understanding impact, general instrument development, and research into therapeutics applications which also incorporate an element of evaluating impact.

b. **Substantial:** Research that is focused towards nanotechnology-based applications or developing fundamental new knowledge on nanoscienee, but that has substantial and explicit relevance to EHS implications. Examples of research in this category would include non-targeted research into biological mechanisms which is informative to understanding risk, instrument development for assessing nanomaterials for applications *and* characterizing nanomaterials in hazard evaluations, and major programs with a significant component focused on risk research.

c. **Some:** Research that is focused on the application of nanotechnology and developing fundamental new knowledge on nanoscience but that has some relevance to EHS implications. Examples might include research into therapeutics applications which also lead to the generation of useful data on hazard.

d. **Marginal:** Fundamental nanoscience and/or nanotechnology applications-based research, which informs understanding on potential EHS implications in a marginal way. Examples might include the development of new analytical techniques such as analytical electron microscopy, where some attempt is made to apply the techniques to understanding potential risks unique to nanomaterials.

Annex B. NNI-Identified Nanotechnology Risk-Research, Listed by Relevance[28]

Highly Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-14	NIST	Single Photon Sources and detectors	
a1-23	NIST	Metrology for the "Fate" of Nanoparticles in Biosystems	
a2-12	NIST	Theoretical Models of Chemical Properties of Nanostructures	
a3-2	NIOSH	Monitoring and Characterizing Airborne Carbon Nanotube Particles	$133,333
a3-3	NIST	Nanoparticle Risk Impact and Assessment Program	
a4-2	NIH	Submicron Particles and Fibers for Toxicological Studies	$168,893
b1-1	DOD	Multidisciplinary University Research Initiative: Effects of Nanoscale Materials on Biological Systems: Relationship between Physiochemical Properties and Toxicological Properties	$1,100,000
b1-2	EPA	Impact of Physiochemical Properties on Skin Absorption of Manufactured Nanomaterials	$130,539
b1-27	NSF	Lung Deposition of Highly Agglomerated Nanoparticles	$133,333
b2-12	NSF	SGER: Aquatic Nanotoxicology of Nanomaterials and Their Biomolecular Derivatives	$30,000
b2-5	NIH	Physicochemical Characterisation and Formulation of Fullerene C60 and Titanium Dioxide	
b2-6	NIOSH	Role of Surface Chemistry in the Toxicological Properties of Manufactured Nanoparticles	$133,333
b2-7	NIOSH	Particle Surface Area As a Dose Metric	$333,333
b2-8	NIOSH	Nanoparticles: Lung Dosimetry and Risk Assessment	$166,667
b2-9	NIOSH	Generation & Characterization of Nanoparticles	$333,333
b3-1	EPA	A Rapid In Vivo System for Determining Toxicity of Manufactured Nanomaterials	$133,333
b3-5	NIH	Development of methods and models for nanoparticle toxicity screening: Applications	$120,109
b4-10	NIOSH	Pulmonary Deposition and Translocation of Nanomaterials	$300,000
b4-11	NSF	Nanotox: Biochemical, Molecular and Cellular Responses of Zebrafish Exposed to Metallic Nanoparticles	$116,667
b4-4	NIH	UTEP-UNM HSC ARCH PROGRAM ON BORDER ASTHMA	$948,159
b4-5	NIH	Skin Penetration, Phototoxicity, and Photocarcinogenesis of Nanoscale Oxides of Titanium and Zinc	
b4-6	NIH	Toxicokinetics of Quantum Dots In Rats	
b4-8	NIOSH	Role of CNT's in Cardiovascular Inflammation & Copd Related Diseases	$300,000
b4-9	NIOSH	Dermal Effects of Nanoparticles	$233,333
b5-1	DOD	Biological Interactions of Nanomaterials	$300,000
b5-2	DOD	Safer Nanomanufacturing	
b5-28	NIH	Nanoparticle Disruption of Cell Function	$122,288
b5-29	NIH	Long Term Cardiovascular Effects of Inhaled Nanoparticles	$118,611
b5-3	DOD	Identifying Critical P-C Characteristics of Np That Elicit Toxic Effects	
b5-30	NIH	Tumorigenicity of Photoactive Nanoscale Titanium Dioxide In Tg.ac Transgenic Mice	
b5-31	NIH	Mechanisms of Chemically Induced Photosensitivity	

[28] Refer to Annex A for definitions of relevance. All research projects in the document "Strategy for nanotechnology-related environmental, health and safety research, Washington DC, National Nanotechnology Initiative." (NNI, 2008) are listed; not all specifically address engineered nanomaterials though, or were funded in 2006.

NNI ID	Agency	Project Title	Estimated Annual Funding
b5-34	NIH	Systemic Implications of Total Joint Replacement	$288,959
b5-35	NIH	Long Term Cardiovascular Effects of Inhaled Nanoparticles	
b5-36	NIOSH	Pulmonary Toxicity of Carbon Nanotube Particles	$300,000
b5-37	NIOSH	Systematic Microvascular Dysfunction Effects of Ultrafine Versus Fine Particles	$200,000
b5-38	NIOSH	Lung Oxidative Stress/Inflammation by Carbon Nanotubes	$375,000
b5-4	EPA	Effects of Ingested Nanoparticles on Gene Regulation in the Colon	$100,000
b7-2	NIOSH	Nanotechnology Safety and Health Coordination	$100,000
c1-1	EPA	Methodology Development for Manufactured Nanomaterial Bioaccumulation Test	$133,256
c1-2	EPA	The Effect of Surface Coatings on the Environmental and Microbial Fate of Nanoiron and Feoxide Nanoparticles	$133,333
c1-3	EPA	Aquatic Toxicity of Waste Stream Nanoparticles	$133,276
c4-1	DOD	Measure The Transport Of Modified Nanoparticles Through Soil	
c4-11	NSF	SGER: Particle Incorporation of PAH in Aquatic Environments: Implications to Fate and Transport	$33,600
c4-14	NSF	CAREER: Interfacial Reactions Affecting Heavy Metal Fate and Transport: An Integrated Research and Education Plan	$78,965
c4-15	NSF	Carbon Nanoparticles in Combustion: A Multiscale Perspective	$80,000
c4-17	NSF	Aggregation and Deposition Behavior of Carbon Nanotubes in Aquatic Environments	$133,333
c4-18	USDA	REACTIVITY, AGGREGATION AND TRANSPORT OF NANOCRYSTALLINE SESQUIOXIDES IN THE SOIL SYSTEM	$61,736
c4-19	USDA	COLLOID INTERFACIAL REACTIONS IN OPEN MICROCHANNEL REPRESENTING UNSATURATED SOIL CAPILLARIES	$48,001
c4-22	USDA	SORPTION AND AVAILABILITY OF METALS AND RADIONUCLIDES IN SOILS	
c4-5	EPA	Ecotoxicology of Underivatized Fullerenes (C60) in Fish	$132,269
c4-6	EPA	Carbon Nanotubes: Environmental Dispersion States, Transport, Fate, and Bioavailability	$123,962
c4-7	EPA	Biological Fate & Electron Microscopy Detection of Nanoparticles During Wastewater Treatment	$132,999
c5-5	NSF	Environmental Biogeochemistry and Nanoscience: Applications to Toxic Metal Transport in the Environment	$60,000
c5-6	NSF	Collaborative Research: Fullerene Aggregation in Aquatic Systems	$116,164
d1-1	NIOSH	Nanotechnology Research Coordination	$233,333
d1-2	NIOSH	Titanium Dioxide (TiO2) Nanoparticle Exposure Study	$133,333
d5-1	DOD	Small Business Innovation Research (SBIR): The Impact of Nanomaterials on Occupational Safety and Health	
d5-2	NIOSH	Nanoparticle in the Workplace	$133,333

NNI ID	Agency	Project Title	Estimated Annual Funding
d5-3	NSF	Experimental and Numerical Simulation of the Fate of Airborne Nanoparticles from a Leak in a Manufacturing Process to Assess Worker Exposure	$133,333
e1-1	NIOSH	Development and Evaluation of Nanofiber-based Filter Media	$333,333
e1-2	NIOSH	Penetration of Nanoparticles Through Respirator Filter Media	$166,667
e1-3	NIOSH	Automobile Ultrafine Intervention	$333,333
e1-4	NIOSH	Assessment Methods for Nanoparticles in the Workplace	$133,333
e2-1	EPA	Comparative Life Cycle Analysis of Nano – and Bulk-materials in Photovoltaic Energy Generation	$100,000
e3-1	NIOSH	Developing a Web-Based Nano-Information Library	$300,000
e5-1	NIOSH	Nanotechnology Information Dissemination	$200,000
e6-2	DOD	WINGS™-Web-Interfaced Nanotechnology ESH Guidance System for Force Health Protection	
e6-5	NSF	NIRT: Nanotechnology in the Public Interest: Regulatory Challenges, Capacity, and Policy Recommendations	$350,000
e6-6	NSF	NIRT: Evaluating Oversight Models for Active Nanostructures and Nanosystems: Learning from Past Technologies in a Societal Context	$305,191

Substantially Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
a2-13	NIST	Nanocharacterization - NCI	
a2-1	DOE	Single Molecule Fluorescence In Nanoscale Environments	
a2-2	DOE	The Reaction Specificity of Nano Particles In Solutions	
b1-16	NIH	Near-Infrared Fluorescence Nanoparticles for Targeted O*	$578,922
b1-18	NIH	NIR Absorbing Nanoparticles For Cancer Therapy	$152,591
b1-19	NIH	A Tumor-Specific Nanoimmunocomplex Markedly Improves MR Imaging	$460,490
b1-23	NIH	CNS Gene Delivery and Imaging in brain Tumor Therapy	$552,763
b1-24	NIH	Nanoparticles for siRNA delivery to mammalian neurons	$166,709
b1-25	NIH	Bioengineering of the blood-brain barrier permeability	$199,169
b1-26	NIH	Reuse in RI: A State-based Approach to Complex Exposures	$2,784,592
b1-4	NIH	Design of Targeting Enhancement for Drug Delivery	$184,653
b1-5	NIH	Nanoparticles for efficient delivery to solid tumors	$111,028
b2-1	NIH	Multifunctional Nanoparticles for Intracellular Delivery	$271,029
b3-4	NIH	Hybrid Nanoparticles in Imaging and Therapy of Prostate*	$585,773
b4-2	NIH	Training in Pharmacometrics and the Therapeutic Application of Nanotechnology	$147,236
b5-20	NIH	Nanoparticles As Promoters of Cell Longevity	$368,831
b5-21	NIH	Nano-Apatite Coating of the Porous Surface of Implants	$249,124
b5-22	NIH	The Interaction of Polycationic Organic Polymers with Biological Membranes	$278,170
b5-26	NIH	Nanotechnology Characterization Laboratory	
b5-32	NIH	Micellar VIP Nanoparticles for Rheumatoid Arthritis	$257,713
a1-17	NIST	Superresolution, In Situ Microscopies for Characterization of Nanostructured Materials	
a4-3	NIST	R&D For Carbon Nanotube Reference Materials	
a4-4	NIST	R&D For Nanoparticle (non-Carbon Nanotube) Reference Materials	
a1-29	NSF	NSEC for Molecular Function at the Nano/Bio Interface	$1,820,700
a3-4	NSF	IMR: Developement of an Analyzer for Size and Charge Characterization of Nanoparticles in Research and Training	$83,676
b2-10	NSF	NIRT: Design of Biocompatible Nanoparticles for Probing Living Cellular Functions and Their Potential Environmental Impacts	$330,938
b2-11	NSF	NER: Novel Cell Culture Stylus for the Rapid Assessment of Functional Nano-Bio Interfaces	$115,300
c4-9	NSF	CAREER: Carbonaceous Particles of Tarry Origin	$110,742

Annex B. Substantially Relevant Research

NNI ID	Agency	Project Title	Estimated Annual Funding
c5-2	NSF	CAREER: An Integrated Research and Education Program in Long-Term Durability of Nano-Structured Cement-Based Materials during Environmental Weathering	$103,331
c5-4	NSF	Investigating the Surface Structure and Reactivity of Bulk and Nanosized Manganese Oxides	$109,857
c5-8	NSF	NSEC: Center for Biological and Environmental Nanotechnology	$937,984
e6-1	NSF	NSEC: Center for Nanotechnology in Society at University of California, Santa Barbara	$885,761
c1-5	USDA	CELLULAR AND MATERIALS-BASED STUDIES OF MARINE INVERTEBRATES TO ADVANCE BIOMINERALIZATION, ANTIFOULING AND NANOTECHNOLOGY FIELDS	
c5-9	USDA	THE CHEMICAL AND PHYSICAL NATURE OF PARTICULATE MATTER AFFECTING AIR, WATER, AND SOIL QUALITY.	

Research with Some Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-32	NSF	Molecular Simulation of Chemical Warfare Agent Adsorption	$35,000
a1-33	NSF	NSEC: Center for Hierarchical Manufacturing	$814,472
b5-33	NIH	Curcumin and Curcumin Derivatives for Alzheimer's	$206,829
a1-34	NSF	Nanoscale Science & Engineering Center for Integrated Nanopatterning and Detection Technologies	$2,117,092
a1-35	NSF	CAREER: Engineering Nucleic Acid Devices	$81,407
a1-36	NSF	NSEC: Center Of Integrated Nanomechanical Systems (COINS)	$1,915,697
b5-39	NSF	NIRT: Controlling Interfacial Activity of Nanoparticles: Robust Routes to Nanoparticle-based Capsules, Membranes, and Electronic Materials	$300,000
a1-1	NIH	A study of model beta-cells in Diabetes Treatment	$298,020
a1-3	NIH	Implantable 16-256 channel data system for sleep in mice	$402,601
b1-3	NIH	Nanoparticle, Raman-based Fiber-optic Glucose Sensor	$377,105
a1-4	NIH	Power Harvesting in Implanted Neural Probes	$190,505
a1-5	NIH	Surface Plasmon-coupled Fluorescence Microscope to Study Ion Channel Dynamics	$186,713
a1-6	NIH	A Turnkey, Wireless, EEG/EMG/Biosensor Measurement	$336,588
b1-6	NIH	Engineered intelligent micelle for tumor pH targeting	$268,607
a1-7	NIH	Cut Nanotube Capsules for MR Imaging (RMI)	$144,603
b1-7	NIH	Carolina Center of Cancer Nanotechnology Excellence	$3,325,006
a1-8	NIH	Flourescent Ceramic Nanoprobes	$323,657
b1-8	NIH	Center of Nanotechnology for Treatment, Understanding, and Monitoring of Cancer	$3,839,972
a1-9	NIH	Targeted MRI with Protein Cage Architectures (RMI)	$354,053
b1-9	NIH	Emory-GA Tech Nanotechnology Center for Personalized and Predictive Oncology	$3,523,612
a1-10	NIH	MFe2O4-Loaded Polymer Micelles as Ultra-Sensitive MR Molecular Probes (RMI)	$351,746
b1-10	NIH	Nanomaterials for Cancer Diagnostics and Therapeutics	$3,695,651
a1-11	NIH	Membrane Topography of Cell Signaling Complexes	$259,841
b1-11	NIH	The MIT-Harvard Center of Cancer Nanotechnology Excellelence	$3,905,825
a1-12	NIH	Non-viral Liver-targeted Gene Delivery	$297,630
b1-12	NIH	The Siteman Center of Cancer Nanotechnology Excellence	$330,773
a1-13	NIH	Morphogen Gradients in Microfluidic Cultures	$138,118
b1-13	NIH	Center of Cancer Nanotechnology Excellence Focused on Therapy Response	$3,806,915
b1-14	NIH	DNA-linked dendrimer nanoparticle systems for diagnosis	$468,218

Annex B. Research with Some Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
b1-15	NIH	NANOTHERAPEUTIC STRATEGY FOR MULTIDRUG RESISTANT TUMORS	$345,707
a1-15	NIST	Quantum Optical Metrology	
a1-16	NIST	Nano-scale Engineered Sensors for Ultra-low Magnetic Field Metrology	
b1-17	NIH	Polymer chelate conjugates for Diagnostic cancer imaging	$239,418
b1-20	NIH	In vivo imaging of diabetogenic cytotoxic T-lymphocytes	$253,117
b1-21	NIH	Imaging Tumor Blood Vessels in Bone Metastases from Breast Cancer	$322,971
b1-22	NIH	Early Detection of Renal Injury	
a1-24	NSF	SST - Ferroelectric Thin-Film Active Sensor Arrays for Structural Health Monitoring	$150,667
a1-25	NSF	CAREER: Hybrid Nanomaterials for Multi-Functional Sensors - Synthesis and Characterization of Nanocomposite Thin-Films for Device Applications	$80,000
a1-26	NSF	CAREER: Integrated Research and Education in Nano- and Microscale Photoacoustic and Photothermal Microscopy	$80,000
a1-27	NSF	REU Site for Nanoscale Structures and Integrated Biosensors (NSIB)	$130,400
a1-28	NSF	Selective Filling of Nanostructured Packings for Chromatographic Chip Systems	$75,000
b1-28	NSF	Nanostructured Interfaces for Targeted Drug Delivery	$25,000
b1-29	NSF	Materials World Network: Designer Nanodiamonds for Detoxification	$157,000
b1-30	NIH	Integrated Nanosystems for Diagnosis and Therapy	$2,713,460
a1-31	NSF	IGERT: Nanoparticle Science and Engineering	$475,747
c2-1	NSF	Environmental Molecular Science Institute: Actinides and Heavy Metals in the Environment - The Formation, Stability, and Impact of Nano- and Micro-Particles	$920,292
b2-2	NIH	Local Anesthetic Cardiotoxicity: Nanotechnology Therapy	$250,062
e2-2	NSF	The Life Cycle of Nanomanufacturing Technologies	$100,000
a2-8	NIH	Toxic Substances in the Environment	$153,032
a2-9	NIH	Bladder Tissue Engineering through Nanotechnology	$170,033
b2-13	NSF	NSEC: Center for Affordable Nanoengineering of Polymer Biomedical Devices (CANPBD)	$2,122,192
a2-14	NIST	Metrology for Tissue Engineering: Test Patterns and Cell Function Indicators	
c3-1	NSF	NER: Nanoscale Size Effects on the Biogeochemical Reactivity of Iron Oxides in Active Environmental Nanosystems	$114,998
a3-1	DOE	A Fundamental Study of Transport Within A Single Nanoscopic Channel	
b3-2	NIH	Polymer-Nucleotide Complexes with Cytotoxic Activity	$226,085
b3-3	NIH	Detecting cancer early with targeted nano-probes for va	$606,348
b3-6	USDA	ROLE OF CHROMOSOME ALTERATIONS IN ENVIRONMENTAL CARCINOGENESIS	
a4-1	NIH	Cryopreservation of tissue engineered substitutes	$320,356

Annex B. Research with Some Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
b4-1	NIH	Treatment of Type 2 Diabetes with Oral Administration of Nanoencapsulated GLP-1	$140,195
c4-2	DOE	How Do Interfacial Phenomena Control Nanoparticle Structure?	
c4-3	DOE	"Frontiers In Biogeochemistry And Nanomineralogy: Studies In Quorum Sensing And Nanosulfide Dissolution Rates	
b4-3	NIH	Pediatric Pharmacology Research Unit	$413,937
a4-5	NIST	Fundamental Metrology for Carbon Nanotube Science and Technology	
a4-6	NIST	Scanning Probe Microscopy Reference Specimens	
c4-8	NIH	Sub-micrometer zero valent metal for in-situ remediation of contaminated aquifers	$64,410
c4-10	NSF	NIRT: Metal Ion Complexation by Dendritic Nanoscale Ligands: Fundamental Investigations and Applications to Water Purification	$305,750
c4-12	NSF	SGER: Metallic Nanocatalysts for Rapid Transformation of Polychlorinated Dibenzo-p-Dioxins	$25,000
c4-13	NSF	Center for Advanced Materials for Water Purification	$4,014,292
c4-16	NSF	Development of a Copolymer-Based System for Targeted Delivery of Nanoparticulate Iron to Environmental Non-Aqueous Phase Liquids	$50,000
c4-20	USDA	ELUCIDATING INTERACTIONS AND TRANSFORMATIONS OF POLLUTANTS AND ORGANIC MATTER IN SOIL	
c4-21	USDA	CONFERENCE SYMPOSIUM: ENVIRONMENTAL MINERALOGY AND TOXIC METALS	$8,500
a5-3	DOE	Directed Energy Interactions With Surfaces	
c5-3	NSF	CAREER: Gas-Phase Catalytic Processes on Metal Nanoclusters	$108,918
b5-5	NIH	Design of Targeting Enhancement for Drug Delivery	$184,653
b5-7	NIH	Pharmacology of Targeted Therapy to Brain Tumors	$365,790
c5-7	NSF	The formation rates and structure of nanodroplets	$131,333
b5-8	NIH	Nanotechnology Platform for Pediatric Brain Cancer Image	$310,464
b5-9	NIH	Multifunctional nanoparticles for targeted DNA vaccine delivery	$137,582
b5-10	NIH	Novel Lentiviral Packaging Systems	$332,556
b5-11	NIH	Translational Program of Excellence in Nanotechnology	$3,081,892
b5-12	NIH	Designing ECM-Inspired Peptide Biomaterials for Regenerative Medicine	$195,077
b5-14	NIH	Nanotechnology in Osseointegration of TMJ Implants	$298,727
a5-14	NSF	Acquisition of a Powder X-ray Diffractometer for Environmental and Materials Research at UC Merced	$93,704
b5-15	NIH	Complex Nanocomposites for Bone Regeneration	$657,312
a5-15	NSF	Engineering Research Center for Extreme Ultraviolet Science and Technology	$2,275,755
b5-16	NIH	BIOMIMETIC SCAFFOLD FOR BONE-REPAIR	$298,530

Annex B. Research with Some Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
b5-17	NIH	Nanotechnology Strategies for Growth of Bones and Teeth	$578,308
b5-18	NIH	Nanocoatings for Biomedical Implants	$211,480
b5-24	NIH	Stimulus-responsive, Mechanically-dynamic Nanocomposite for Cortical Electrodes	$199,718
b5-25	NIH	Mechanisms of Orthopedic Implant Osteolysis	$23,799
b5-27	NIH	Imaging Nanocomposites Targeting Tumor Microvasculature	$254,829
a6-1	NSF	Idaho Research Infrastructure Improvement	$3,000,000
e6-3	NSF	NSEC: The Center for High-rate Nanomanufacturing (CHN)	$2,033,540
e6-4	NSF	NSEC: Templated Synthesis and Assembly at the Nanoscale	$2,135,780
c7-2	NSF	Reactive Membrane Technology for Water Treatment	$101,062
c7-3	NSF	Magnetocaloric Effect in Nanoparticle Assemblies for Refrigeration Applications	$50,000
c7-6	NSF	NIRT: Active Nanoparticles in Nanostructured Materials Enabling Advances in Renewable Energy and Environmental Remediation	$278,000
c7-10	NSF	CAREER: On the Prevention of Selenium and Arsenic Release into the Atmosphere	$79,952
c7-11	NSF	Nanoscale Mineralogy and Geochemistry of Arsenian Pyrite in Ore Deposits	$71,741

Research with Marginal Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
a1-2	NIST	Develop Fiber-Optic Confocal Microscope With Nanoscale Depth Resolution	
a1-18	NIST	Metrology of Semiconductor Quantum Nanowires	
a1-19	NIST	High Throughput Hyperspectral Data Analysis	
a1-20	NIST	Dimensional Metrology Program	
a1-21	NIST	Surface Metrology	
a1-22	NIST	Phase Sensitive Scatterfield Imaging for Sub-10 nm Dimensional Metrology	
a1-30	NSF	National High Magnetic Field Laboratory	$28,647,208
a2-3	DOE	Manipulation and Quantitative Interrogation of Nanostructures	
b2-3	NIH	Bioabsorbable Membranes for Prevention of Adhesions	$415,114
a2-4	DOE	Diffraction Studies of Glasses, Liquids, and Nanoclusters	
b2-4	NIH	NanoMedex Propofol Microemulsions: Preclinical Studies to FDA IND Application	$411,614
a2-5	DOE	New Methods and Instrumentation For the Study of Complex Magnetic Materials and Nanostructures Using Soft X-ray Spectroscopies	
a2-6	DOE	Using Plasmon Peaks In Electron Energy-Loss Spectroscopy To Determine the Physical and Mechanical Properties of Nanoscale Materials	
a2-7	DOE	Nano-structures Examined With Spin-polarized Positron Beams	
a2-10	NIH	Nano-Porous Alumina Membranes for Enhanced Hemodialysis Performance	$183,400
a2-11	NIH	Biotechnology Research Infrastructure at Albany State U*	$793,298
a5-1	DOE	Chemical Analysis of Nanodomains	
c5-1	DOE	Experimental, Theoretical, And Model-based Studies Of Crystallographically Controlled Self-assembly During Nanocrystal Growth	
a5-2	DOE	Atomic Scale Chemical Imaging In 3 Dimensions	
a5-4	DOE	Studies of Nanoscale Structure and Structural Defects of Advanced Materials	
a5-5	DOE	Microscopy Investigations of Nanostructured Materials	
a5-6	DOE	Three-dimensional Imaging of Nanoscale Materials By Using Coherent X-rays	
b5-6	NIH	USING VIRAL NANOPARTICLES TO TARGET CANCER	$726,937
a5-7	DOE	Electron Diffraction Determination of Nanoscale Structures	
a5-8	DOE	Quantitative Electron Nano-crystallography and Nano-spectroscopy	
a5-9	DOE	High Resolution Lenseless 3d Imaging of Nanostructures With Coherent X-rays	
a5-10	NIH	Thin-walled Micromolding	$336,916

Annex B. Research with Marginal Relevance

NNI ID	Agency	Project Title	Estimated Annual Funding
a5-11	NIST	3-D Chemical Imaging at the Nanoscale	
a5-12	NIST	Metrology for the Manufacture of Robust Nanostructures	
b5-13	NIH	New Nanoparticles for Antimicrobial Therapy of Dental Plaque Related Diseases	$145,988
a5-13	NSF	CAREER: Multi-Scale and Multi-Disciplinary Aspects of Indentation	$79,923
b5-19	NIH	Center of Excellence in Translational Human Stem Cell Research	$893,968
b5-23	NIH	Reconfigurable Nanoengineered Extracellular Matricss	$172,163
a6-2	NSF	NNIN: National Nanotechnology Infrastructure Network	$11,180,430
a7-1	NSF	SGER: MEMS-Based Preconcentrators with Nano-Structured Adsorbents for Micro Gas Chromatography	$50,000
c7-1	NSF	New Mexico EPSCoR RII (NM NEW) Proposal	$1,687,500
c7-4	NSF	Delaware Research Infrastructure Improvement Program	$2,000,000
c7-5	NSF	Alabama Research Infrastructure Improvement	$2,066,667
c7-7	NSF	NIRT: Actively Reconfigurable Nanostructured Surfaces for the Improved Separation of Biological Macromolecules	$250,000
c7-8	NSF	NIRT: Environmentally Benign Deagglomeration and Mixing of Nanoparticles	$304,688
c7-9	NSF	CAREER: Hydroxyl Radical and Sulfate Radical-Based Advanced Oxidation Nanotechnologies for the Destruction of Biological Toxins in Water	$85,524

BIOGRAPHY FOR ANDREW D. MAYNARD

Dr. Andrew Maynard is the Chief Science Advisor to the Project on Emerging Nanotechnologies-an initiative dedicated to helping business, government and the public anticipate and manage possible health and environmental implications of nanotechnology. Dr. Maynard is considered one of the foremost international experts on addressing possible nanotechnology risks and developing safe nanotechnologies. As well as publishing extensively in the scientific literature, Dr. Maynard is a well-known international speaker on nanotechnology, and frequently appears in print and on radio and television.

Dr. Maynard trained as a physicist at Birmingham University in the UK. After completing a Ph.D. in ultrafine aerosol analysis at the Cavendish Laboratory, Cambridge University (UK), he joined the aerosols research group of the UK Health and Safety Executive, where he led research into aerosol behavior and characterization.

In 2000, Dr. Maynard joined the National Institute for Occupational Safety and Health (NIOSH), part of the U.S. Centers for Disease Control and Prevention (CDC). Dr. Maynard was instrumental in establishing the NIOSH nanotechnology research initiative, which continues to lead efforts to identify, assess and address the potential impacts of nanotechnology in the workplace. Dr. Maynard also represented NIOSH on the Nanomaterial Science, Engineering and Technology subcommittee of the National Science and Technology Council (NSET), and he co-chaired the Nanotechnology Health and Environment Implications (NEHI) working group of NSET. Both are a part of the National Nanotechnology Initiative (NNI), the federal research and development program established to coordinate the U.S. Government's annual $1 billion investment in nanoscale science, engineering, and technology.

Dr. Maynard continues to work closely with many organizations and initiatives on the responsible and sustainable development of nanotechnology. He is a member of the Executive Committee of the International Council On Nanotechnology (ICON), he has chaired the International Standards Organization Working Group on size selective sampling in the workplace, and he has been involved in the organization of many international meetings on nanotechnology. Dr. Maynard has testified before the U.S. House Committee on Science & Technology on nanotechnology policy, and is a member of the President's Council of Advisors on Science and Technology, Nanotechnology Technical Advisory Group. Dr. Maynard is an Honorary Senior Lecturer at the University of Aberdeen, U.K., and has authored or co-authored over 100 scholarly publications.

Chairman GORDON. Thank you, Dr. Maynard. Dr. David is recognized.

STATEMENT OF DR. RAYMOND DAVID, MANAGER OF TOXICOLOGY FOR INDUSTRIAL CHEMICALS, BASF CORPORATION

Dr. DAVID. Good morning, Mr. Chairman and Members of the Committee. I am Dr. Raymond David. I am a toxicologist with BASF Corporation, but I am here on behalf of the American Chemistry Council and Nanotechnology Panel to speak in favor of the *National Nanotechnology Initiative Amendments Act of 2008*.

The infrastructure that the amendment would provide will greatly improve the ability of the United States to plan, coordinate, and implement research programs, especially ones focused on the safe use of nanotechnology. The infrastructure and focus will be welcome in an area that has seen an explosion of research and experimental data in the scientific literature but not necessarily always focused on addressing any one particular issue. Under the NNI amendment, a central, federal research oversight function will be created to address specific research questions and provide the capability to utilize all the federal research resources available to answer any one particular question, much like other governments around the globe.

This central oversight will bring the strengths of organizations such as the EPA, NIH, NCTR, and the National Characterization

Laboratory together to resolve a particular question, and they can do that in a fashion that will be much faster than academia or industry alone could resolve.

The amendments mandate that NNI provide information to the academic and industrial research communities on current research programs, so that we can reduce the redundancy on some of the experiments we see, available techniques and methodologies, and facilities that can support robust scientific research. This information will be welcome in an area that we have seen a lot of redundancy in terms of the scientific literature and hopefully gain acceptance of minimal characterization evaluation parameters so that people will know exactly what the characteristics of the nanomaterials are that they are testing. This is something that is presently lacking and would otherwise make their research uninterpretable.

The ACC strongly supports the intention to educate all stakeholders, especially the public, on nanotechnology. I think we are at a crossroads in terms of the public perception with respect to the uses of nanomaterials. Some of the information that the public receives from the media tends to overemphasize the uncertainties of nanotechnology. We believe that it is important that the public understand the true risks and benefits of this technology and the nanomaterials that are being used, and they need to receive that in a very clear, straightforward manner.

Of course, these amendments and the infrastructure that they creates does not guarantee success. The proof is really in the pudding. The implementation is what is important. The ACC would also like to re-emphasize that a comprehensive and prioritized federal research strategy focusing on EHS concerns is still missing. What we need to do is we need to focus on assessments of risks to health and the environment. We need to promote new interdisciplinary relationships. We need to support better understanding of the fundamental properties of nanomaterials and how that impacts the risk assessment. We need to develop processes for establishing standard protocols so that individual and maybe categories of nanomaterials can be evaluated. We need to clearly delineate the responsibilities, programs, timelines, and anticipated results of funded projects. And I think we need to leverage planned research that is ongoing throughout the world, particularly in the OECD. We have previously urged an independent review by the National Research Council's Board of Environmental Studies and Toxicology to establish research priorities for manufactured nanomaterials. We continue to believe that that is an important effort that should be pursued so that we can develop a comprehensive roadmap with appropriate projects and priorities and evaluation metrics.

The nanotechnologies panel member companies want to foster responsible application of nanotechnology. We want to share and coordinate EHS initiatives, and we want to facilitate the exchange of information.

We look forward to working with the Congress and NNI to make the implementation of these amendments a success. We hope the bill will be passed, and we look forward to that happening. Thank you.

[The prepared statement of Dr. David follows:]

PREPARED STATEMENT OF RAYMOND DAVID

Good Morning Chairman Gordon and Members of the Committee. I am Dr. Raymond David, a toxicologist with BASF Corporation, and appearing before you today on behalf of the American Chemistry Council and ACC's Nanotechnology Panel to speak in favor of the *National Nanotechnology Initiative Amendments Act of 2008.*

I appreciate Chairman Gordon's invitation to address the House Committee on Science and Technology on the role of the National Nanotechnology Initiative (NNI) in planning and implementing the environmental, safety, and health research necessary for the responsible development of nanotechnology.

ACC represents the leading companies engaged in the business of chemistry. ACC members apply the science of chemistry to make innovative products and services that make people's lives better, healthier and safer. In 2005, ACC formed its Nanotechnology Panel consisting of domestic producers that are engaged in the manufacture, distribution, and/or use of chemicals that have a business interest in the products of nanotechnology. Panel member companies wish to foster the responsible application of nanotechnology; to coordinate nanotechnology environmental, health, and safety research initiatives undertaken by member companies and other organizations; and to facilitate the exchange of information among member companies and other domestic and international organizations on issues related to applications and products of nanotechnology.

The infrastructure that the NNI amendments would create will greatly improve the ability of the U.S. to plan, coordinate, and implement research programs—especially ones focused on the safe use of nanomaterials, an issue that has been raised many times in the past few years. This infrastructure and focus will be welcome in an area that has seen an explosion of research and generation of experimental data—not always focused. The U.S. has had many intellectual and financial resources applied to studying nanomaterials, but not necessarily directed at solving any one issue. Under the NNI amendment, a central, federal, research oversight function would be created to address specific research questions and provide the capability to utilize all federal resources to answer those questions—much like other governments throughout the globe.

This centralized oversight will bring the strengths of each federal research organization together to address a single issue. For example, scientists in the National Characterization Laboratory in Frederick, MD, have extensive experience detecting a variety of nanomaterials in biological fluids; scientists in NIOSH have verified the protective effect of personal protective equipment and have investigated the cellular effects of dermal exposure; and scientists in NIEHS and NCTR have developed techniques and conducted experiments to better understand the potential for dermal penetration of nanomaterials. Being able to bring all these entities and expertise together to answer specific questions on the applied nanomaterials could bring swift answers to questions that would take industry or academia alone much longer to evaluate.

The amendments would also mandate that NNI provide information to the academic and industrial research community on current research programs, available techniques and methodologies, and facilities to support robust scientific research. This information should reduce the redundancy that we currently find in the explosion of scientific literature, and help gain acceptance of minimal characterization criteria needed for understanding the nature of what particle was tested—nano sized or otherwise. Too often we find published studies that refer only to obtaining a nanomaterial from a vendor and adding that to a biological test system. Investigators need to know how and where they get characterized nanomaterials for study. Otherwise, their research may be difficult to interpret in the context of human or environmental safety assessment.

ACC strongly supports the amendment's purposes to have NNI provide support for programs designed to educate all stakeholders, including the public, on nanotechnology. The public may very well have a skewed perception of nanotechnology and specifically the use of nanomaterials. Sensational articles on nanotechnology in the mainstream media can distort information, and we all must be mindful of the urgent need to present information on nanotechnology in a factually accurate, balanced way. The public will be far less likely to be receptive to this emerging technology if information about its potential risks and benefits is not faithfully reported in clear, straightforward terms.

Of course, the infrastructure that these amendments would provide does not guarantee success. Implementation is what is important. ACC would also like to re-emphasize that a high quality, comprehensive and prioritized federal research strategy focusing on nanotechnology environment, health, and safety is still missing and should:

- Focus on risk assessments, and the generation and application of information on the continuum of exposure, dose and response;
- Promote new interdisciplinary partnerships that bring visionary thinking to research on nanotechnology;
- Support better understanding of the fundamental properties of nanomaterials that have an impact in the exposure-dose-response paradigm;
- Develop processes for establishing validated standard measurement protocols so that individual or categories of materials can be studied;
- Clearly delineate the responsibilities, programs, timelines, and anticipated results of funded projects for each federal agency; and
- Leverage planned and ongoing work by the Organization for Economic Cooperation and Development's (OECD) Working Party on Manufactured Nanomaterials, particularly in identifying on-going or planned research projects by other countries and interpreting the results of this research, and the testing of representative nanomaterials using standard test methods to assess potential health or environmental hazards.

When ACC testified before you last October, we urged as an appropriate next step, the funding of an independent review by the National Research Council Board of Environmental Studies and Toxicology (BEST) to establish EHS research priorities for manufactured nanomaterials and a substantial increase in federal funding of EHS programs for manufactured nanomaterials. ACC continues to believe that BEST should develop and monitor implementation of a comprehensive roadmap for federal EHS research projects and set priorities with evaluation metrics suitable for federal funding. This funding would enable BEST to develop a roadmap and strategy for the Federal Government for environmental, health, and safety research.

We look forward to working with the Congress and NNI to make the implementation of the NNI amendments a success. We are hopeful that this bill will be passed to allow that to happen.

BIOGRAPHY FOR RAYMOND DAVID

Dr. Raymond David is Manager of Toxicology for Industrial Chemicals in BASF Corporation. He received his Ph.D. in Pharmacology from the University of Louisville, after which he was a Postdoctoral Fellow at the Chemical Institute of Toxicology in Research Triangle Park. Dr. David worked for eight years at Microbiological Associates in Bethesda, Maryland where he managed the Inhalation and Mammalian Toxicology Departments. He also spent 14 years at Eastman Kodak in Rochester New York as Senior Toxicologist before joining BASF in 2006. Dr. David has experience conducting inhalation, pulmonary, reproductive, and systemic toxicity studies. He was responsible for EH&S issues for nanotechnology at Eastman Kodak Company, and is currently responsible for nanotechnology issues in BASF Corporation.

Chairman GORDON. Thank you, Dr. David. Finally, Dr. Doering, you are recognized.

STATEMENT OF DR. ROBERT R. DOERING, SENIOR FELLOW AND RESEARCH STRATEGY MANAGER, TEXAS INSTRUMENTS

Dr. DOERING. Chairman Gordon, Members of the Committee, thank you for the opportunity to testify today on the *National Nanotechnology Initiative Amendments Act of 2008.* Texas Instruments and the Semiconductor Industry Association view two topics as key to the legislation, first, identification of areas of national importance and second, translation of basic research into commercialization. These are essential to ensuring that the NNI program maintains U.S. leadership in nanotechnology and contributes to economic competitiveness.

Appropriately, the bill identifies four areas of national importance: electronics, health care, energy, and water purification. This will prioritize interagency activities and resources around nanotechnology research to address critical challenges facing our country. The INSI are encouraged that electronics is the first area

listed and strongly advocates that it be renamed as nanoelectronics. Nanoelectronics will actually play a key role in essentially every area of national importance. It will enable improved information processing, communications, imaging and sensor technologies that will assist in addressing energy challenges, improving health care, and detecting national security threats. Advanced nanoelectronics research is needed because the CMOS technology that the semiconductor industry has used for over 30 years is projected to reach its performance, energy efficiency, and cost limits by the year 2020. In 2005, six U.S. semiconductor companies formed a consortium, the Nanoelectronics Research Initiative, to provide industry funds to universities to accelerate this research. Today, the NRI leverages funding and expertise from industry, NSF, and NIST, as well as contributions from state and local governments and supports research at 35 universities and four regional centers.

This collaboration model can be replicated to address other national challenges with nanotechnology research. The draft legislation recognizes and encourages such models. To effectively pursue research in the areas of national importance, universities and federal labs will need adequate resources for research funding and essential equipment. NNI investments in the areas of national importance should be reported in the same manner that they currently are for the program component areas.

The bill recognizes the basic nanotechnology research should lead to commercial applications. Industry can play an important role in establishing a balance between directed basic research and its potential commercialization by providing insights on an appropriate goals and needs for both. For example, there are a number of candidates for new nanoelectronics devices, but to be viable these must be capable of being manufactured in commercial volumes at low cost. This may require an entirely new nanomanufacturing paradigm.

Also, as we move nanoelectronics to even smaller dimensions, the metrology challenges will only increase, an important role for NIST. Thus, the bill's call for instrumentation and tools for nanoscale manufacturing is a significant element for the semiconductor industry. In addition, the draft legislation rightly identifies the important role of state leverage through research, development, and technology transfer initiatives. The State of Texas, the University of Texas System, and Texas Industry collaborated to establish a $30 million complimentary package of leveraged funding to attract and support top academic researchers at the Southwest Academy of Nanoelectronics which is one of the regional centers in NRI. Currently, the NRI state and local leverage for all regional centers totals about $15 million annually.

In conclusion, while the legislation establishes an important framework, corresponding appropriations will need to follow. We look forward to continuing our work with this committee to successfully achieve the funding goals of America COMPETES and the President's American Competitiveness Initiative as the *National Nanotechnology Amendments Act of 2008* moves towards final passage. Thank you.

[The prepared statement of Dr. Doering follows:]

PREPARED STATEMENT OF ROBERT R. DOERING

Chairman Gordon, Ranking Member Hall, Members of the Committee, thank you for the opportunity to testify today on the *National Nanotechnology Initiative Amendments Act of 2008.* This legislation is a natural follow-on to the *America COMPETES Act* signed into law last summer, and we thank this committee for playing such a critical leadership role in that effort.

Texas Instruments (TI) has a 78-year history of innovation. While our products have changed many times over the years, we have always fundamentally been a company of engineers and scientists. We have always looked to the future by investing in R&D. Based in Dallas, TI has become the world's third largest semiconductor company. TI is focused on developing new electronics that make the world smarter, healthier, safer, greener and more fun.

I am also appearing on behalf of the Semiconductor Industry Association (SIA). SIA has represented America's semiconductor industry since 1977. The U.S. semiconductor industry has 46 percent of the $257 billion world semiconductor market. The semiconductor industry employs 216,000 people across the U.S., and is America's second largest export sector.

While my testimony today focuses directly on the draft *National Nanotechnology Initiative Amendments Act,* please note that TI strongly supports the testimony presented last month to the Subcommittee on Research and Science Education by Dr. Jeff Welser, Director of the Nanoelectronics Research Initiative (NRI) at the Semiconductor Research Corporation on assignment from IBM. TI is an active member of the NRI, as well as the Semiconductor Research Corporation and the Semiconductor Industry Association.

Nanotechnology holds the promise of solving a number of major challenges facing our country, in areas such as energy, health care, and security. Nanotechnology research is extremely interdisciplinary, bringing together any combination of biologists, chemists, electrical engineers, physicists, medical doctors and materials scientists. This interdisciplinary nature is one of the reasons that it is essential federal research agencies be encouraged to work collaboratively in the field of nanotechnology.

The *21st Century Nanotechnology Research and Development Act* signed into law in 2003 created the mechanism to coordinate federal research agencies on a major scale around this subject. The creation of the National Nanotechnology Coordinating Office (NNCO) provided a focal point of these federal activities, leading to the development of strategic plans that identified program component areas, and brought together key stakeholders for workshops on major nanotechnology topics.

The *National Nanotechnology Initiative Amendments Act of 2008* expands upon the foundation of the original legislation to improve interagency activities on critical nanotechnology research. Section 2 contains a number of elements that would enhance the way National Nanotechnology Initiative (NNI) is planned and implemented. Using the NNI strategic plan to establish clear metrics and time frames for both near- and long-term objectives, including plans for technology transition with industry and the states, allows better measurement of progress towards NNI goals. The explicit funding mechanism for the NNCO and authorization of travel expenditures are also positive proposals for improving the way the NNI is planned and implemented. The modifications to the Advisory Panel will allow a more direct role for industry input and specific focus on nanotechnology. While PCAST has addressed nanotechnology on a detailed level, it also has a vast scope of work in a range of other areas.

My testimony today will focus on two core aspects that TI and the U.S. semiconductor industry see as key components to the legislation: identification of areas of national importance and the translation of basic research into innovations that can be commercialized. These are essential to ensuring that the NNI program maintains U.S. leadership in nanotechnology.

Areas of National Importance (Section 5)

The draft legislation's inclusion of "Areas of National Importance" is an essential element to the bill. The identification of the areas specifically named in the bill as well as subsequently by the Advisory Panel, will facilitate prioritization of interagency activity and resources around nanotechnology research that addresses the most critical challenges facing our country. It is indeed appropriate with this legislation for Congress to set some initial areas of national importance, with flexibility embodied in the Advisory Panel to identify additional areas. The legislation importantly recognizes that the projects in these areas will be selected on a merit and competitive basis.

The draft bill identifies electronics, health care, energy, and water purification as initial areas of national importance. TI and the U.S. semiconductor industry are encouraged that electronics is the first area listed, and strongly advocate that it be renamed nanoelectronics and that the reference be retained in the final bill.

The semiconductor industry makes major contributions to the U.S. economy. Semiconductor price reductions and performance improvements have driven productivity. Semiconductors drive the information technology sector, which has contributed to 25 percent of gross domestic product (GDP) growth since 1995 while only making up three percent of GDP. U.S. semiconductor companies are technology leaders, capturing nearly half of the over $250 billion worldwide market.

As Dr. Welser testified, nanoelectronics research is needed to advance the current semiconductor technology to its ultimate limits, and to examine nanoelectronics alternatives to go beyond those limits, which will probably be reached by around 2020.

Progress in nanoelectronics is essential to continued advances in information and communications, enabling breakthroughs in applications that depend on rapidly accessing huge volumes of data and increasing the speed of computations with that data, such as improved mapping of the human genome and protein folding, predicting the path of hurricanes, and modeling the behavior of nanomaterials and nanoparticles. There is no doubt that nanoelectronics will play a key role in essentially every area of national importance, such as energy, health care, and national security.

In addressing energy challenges, nanoelectronics and nanostructured materials will be essential to developing new sources as well as to greatly improved means of energy harvesting, storage, distribution, conservation, scavenging, and exploration. Nanostructured materials are already showing promise for low-cost, high-efficiency solar cells, fuel cells, super capacitors, batteries, and light-emitting diodes (LEDs).

As our country faces rising health care costs for a growing and aging population, the application of nanotechnology to medical diagnoses and treatments will be critical. Advances in nanoelectronics, and nanotechnology more broadly, can lead to less invasive procedures, better imaging and monitoring, and targeted treatment at the cellular level (e.g., cancer).

Security is another major area of national importance. Even if the Committee decides not to address this area in the legislation, this topic should certainly be prominent in the interagency context. Further progress in nanoelectronics will continue to benefit national security in very many ways, including even smarter weapons, better and quicker situational awareness, and a broad range of small sensors such as single-chip chemical and biological analysis platforms.

Models and Resources Required to Address National Areas

Collaboration among Federal and State government, industry, and academia will be essential in addressing the application of nanotechnology to national challenges, through partnerships such as the NRI. The NRI currently supports university basic research in nanoelectronics at 35 universities and four regional centers. NRI efforts are primarily focused on finding a new switch with improved speed, energy efficiency, and/or cost compared to the field-effect transistor, which is today's workhorse for processing information. The National Science Foundation also recognized this nanoelectronics challenge in its 2009 budget request by including a $20M initiative for research addressing "Science and Engineering Beyond Moore's Law."

The NRI started as a result of the semiconductor industry recognizing that university research in nanoelectronics must be accelerated. In 2005, Advanced Micro Devices, Freescale, IBM, Intel, Micron Technology, and Texas Instruments all agreed to provide industry funds to form a consortium that would fund university research in nanoelectronics. From the beginning, it was clear that the scope of the challenge and basic science questions involved would require engagement and resources from the Federal Government, and conversations began with NSF and NIST.

NRI is a model collaboration that leverages funding and expertise from industry, NSF, and NIST, and contributions from State and local governments. To quote the most recent NNI strategic plan profile of the NRI, "these government-industry-academic partnerships blend the discovery mission of NSF, the technology innovation mission of NIST, the practical perspective of industry, and the technical expertise of U.S. universities to address a nanotechnology research and development priority. It is one example of the creative methods the NNI uses to accelerate research that contributes to the Nation's economic competitiveness." We are pleased that the draft legislation recognizes and encourages such models in Section 5.

An extremely valuable addition to the reporting requirement in Section 5 would be to track investments in the areas of national interest, at the same level of detail

as is currently done for the Program Component Areas. This information is currently disaggregated across agencies and extremely difficult to obtain and compile. For example, there is no central location to determine overall federal investments in nanoelectronics research, and certainly not on a fiscal year-to-year basis to determine trends.

To pursue critical research in the areas of national importance, universities and federal labs such as NIST will need adequate resources in terms of research funding and necessary equipment/relating operating costs—this should be recognized in the bill. While the *National Nanotechnology Initiative Amendments Act of 2008* establishes an important framework, corresponding appropriations will need to follow. TI and many of our colleagues in the U.S. semiconductor industry have been among the leaders in the business community advocating for appropriations to meet the research levels established by the *America COMPETES Act,* House Democratic Innovation Agenda, and the President's American Competitiveness Agenda.

Research to Commercialization (Sections 4 and 6)

The Federal Government is uniquely positioned to fund basic research. Historically, it has been the primary source of basic research funds for universities. The Federal Government plays an especially important role in supporting higher-risk, exploratory research for which the economic benefits may not be realized for decades.

We applaud the Committee for recognizing that appropriate critical areas of basic research must have a mechanism for translating research into commercial applications. This must be balanced with sustained emphasis on continuing the exploratory research itself, which is required to answer remaining fundamental questions in the science and engineering of nanotechnology. We believe that industry can play an important role in establishing this balance by providing insights on appropriate goals and needs for both "directed" basic research and its potential commercialization. This input can be provided through the revised Advisory Panel, consortia, and various industry advisory liaisons' input into federal agency merit review processes. Direct agency partnership through pre-competitive industry consortia is one of the best mechanisms to achieve close industry-government collaboration and facilitate commercialization of promising research.

Nanomanufacturing

The language in Section 6 calling for instrumentation and tools for nanoscale manufacturing is an important one for the semiconductor industry. As we move to nanoelectronics, measurement, or metrology, challenges will only increase. NIST is best suited to address these challenges given its mission of metrology and its laboratory resources.

Using the NRI research as an example, the new nanoelectronics switch must be extremely reliable, fast, low power, functionally dense, and capable of being manufactured in commercial volumes at low cost. There are a number of candidates for the new nanoelectronics switch, including devices based on spin or other quantum state variables rather than classical bulk electric charge. Commercialization of such devices into a new class of integrated circuits may very well require an entirely new nanomanufacturing paradigm.

Role of the States

Section 4 of the draft legislation highlights technology transfer and explicitly identifies the important role of State leverage through research, development, and technology transfer initiatives.

We agree that State governments should play an important role in leveraging federal funds and facilitating commercialization from universities to industry. For example, Texas created a $200 million Emerging Technology Fund. The fund has three goals: invest in public-private endeavors around emerging scientific or technology fields tied to competitiveness; match federal and other sponsored investment in science; and attract and enhance research talent superiority in Texas. Several other states have similar mechanisms. Of course, State governments are also critical in supporting public research universities from an overall budget perspective.

As part of the establishment of the third regional NRI center, the Southwest Academy of Nanoelectronics (SWAN), the State of Texas, the University of Texas System, and Texas industry collaborated to establish a complementary package of leveraged support. The resulting $30 million of matching funds is focused on attracting and supporting top academic researchers in nanoelectronics. Specifically, this is a three-way match, with the State of Texas contributing $10 million from the Emerging Technology Fund, the University of Texas System matching with $10 mil-

lion, and the remaining $10 million being contributed by Texas industry for endowed chairs, including $5 million from TI.

The other regional NRI centers provide similar State and local leverage to industry, NSF, and NIST funds. Overall, states are contributing approximately $15 million annually to the NRI in funding, equipment, and endowments, in addition to the major investments in new buildings. New York has provided significant research funding for the Institute for Nanoelectronics Discovery and Engineering (INDEX), as well as a major expansion of the College of Nanoscale Science and Engineering Complex in Albany. The State of Georgia, a partner in INDEX through Georgia Tech, has provided new facilities. The Western Institute of Nanoelectronics (WIN) Center has leveraged funds through the University of California's Discovery program. The recently-established Midwest Academy for Nanoelectronics and Architectures (MANA) at Notre Dame has attracted Indiana State funds and even city resources from South Bend, as well as a commitment to a nanoelectronics building and adjacent innovation park for commercialization activities.

While the states have provided these resources to the four regional NRI centers, it is important to note that the regional centers are "virtual" and involve researchers from several universities outside these states, thus the local investments benefit research on a national level.

The President's Council of Advisors on Science and Technology issued a five-year assessment report on the NNI in 2005. One of the recommendations was to increase federal cooperation with the states, especially by leveraging State research investments. Further, the report recognized the important role of states in commercializing nanotechnology research results. We agree with these conclusions and endorse the draft legislation's emphasis on the role of the states in nanotechnology.

Conclusion

Thank you for the opportunity to testify on *National Nanotechnology Initiative Amendments Act of 2008.* The draft bill makes a number of improvements to the planning and implementation of the NNI. We strongly support the focus on areas of national interest, and specifically the language on nanoelectronics. The translation of basic research to commercialization must occur to ensure that the NNI maximizes the contributions to U.S. economic competitiveness and maintains our country's leadership in nanotechnology. TI and the semiconductor industry look forward to continuing to work closely with the Committee as this bill proceeds towards final passage.

BIOGRAPHY FOR ROBERT R. DOERING

Dr. Doering is a Senior Fellow and Technology Strategy Manager at Texas Instruments. He is also a member of TI's Technical Advisory Board. His previous positions at TI include: Manager of Future-Factory Strategy, Director of Scaled-Technology Integration, and Director of the Microelectronics Manufacturing Science and Technology (MMST) Program. The MMST Program was a five-year R&D effort, funded by DARPA, the U.S. Air Force, and Texas Instruments, which developed a wide range of new technologies for advanced semiconductor manufacturing. The major highlight of the program was the demonstration, in 1993, of sub-three-day cycle time for manufacturing 350-nm CMOS integrated circuits. This was principally enabled by the development of 100 percent single-wafer processing.

He received a B.S. degree in physics from the Massachusetts Institute of Technology in 1968 and a Ph.D. in physics from Michigan State University in 1974. He joined TI in 1980, after several years on the faculty of the Physics Department at the University of Virginia. His physics research was on nuclear reactions and was highlighted by the discovery of the Giant Spin-Isospin Resonance in heavy nuclei in 1973 and by pioneering experiments in medium-energy heavy-ion reactions in the late 70's. His early work at Texas Instruments was on SRAM, DRAM, and NMOS/CMOS device physics and process-flow design. Management responsibilities during his first 10 years at TI included advanced lithography and plasma etch as well as CMOS and DRAM technology development.

Dr. Doering is an IEEE Fellow and Chair of the Semiconductor Manufacturing Technical Committee of the IEEE Electron Devices Society. He represents Texas Instruments on many industry committees, including: the Technology Strategy Committee of the Semiconductor Industry Association, the Board of Directors of the Semiconductor Research Corporation, the Governing Council of the Focus Center Research Program, the Governing Council of the Focus Center Research Program, the Governing Council of the Nanoelectronics Research Initiative, and the Corporate Associates Advisory Committee of the American Institute of Physics. Dr. Doering is

also a founder of the International Technology Roadmap for Semiconductors and one of the two U.S. representatives to the International Roadmap Committee, which governs the ITRS. He has authored/presented over 150 publications and invited papers/talks and has 20 U.S. patents.

DISCUSSION

Chairman GORDON. Thank you, Dr. Doering. You are absolutely right. We have got to do more than authorize. We have also got to follow up with those appropriations. Thank you.

At this point, we will open ourselves for the first round of questions, and the Chair recognizes himself. There has been a lot of discussion this morning about health and safety, environmental concerns about nanotechnology. Let me tell you the reasons that I am particularly concerned about that. One is my seven-year-old daughter, and I know all of us have reasons of some nature, that same interest. The other is I want to make sure that America gets as much bang for the buck of our investment as we can. I want us to be first to market. I want us to be able to create jobs in this country built around nanotechnology. And as a son of a farmer, I am haunted to some extent about what I have seen with genetically altered grain. I have seen how it has been rejected, even though in my opinion we have had good research to the contrary around the world. I don't want that to happen here. I think that means we have got to get out in front. There are already 600 products on the market, and it concerns me that we are going to have a horror story with one out of 600, and it could put a taint on the entire industry.

For that reason, the draft bill requires that 10 percent of the NNI's total funding be designated for the environmental, health, and safety research component area there at NNI. This would be about $150 million under the current 2009 request. Now, this is a provision that has been really recommended by a number of companies within industry, academia, NGO. It is consistent with the National Academy of Science 2006 review of NNI. But it is not unanimous, and Mr. Kvamme, you have stated, and I will quote, that it is misguided and may have the unintended consequence of reducing research on beneficial applications and on risk. So let me ask you, do you feel like your panel is satisfied with the current level of funding on health, environment, and safety?

Mr. KVAMME. Well, as I mentioned in my testimony, we in our report, we call for increased spending in that area and particularly since the industry is picking up more and more research funding in the nano area, we think the Government's role will in fact change. As you know very well, the 2009——

Chairman GORDON. Change in what direction?

Mr. KVAMME. In an increasing direction. In the 2009 request——

Chairman GORDON. In an increasing direction? You said it was going to change. From what to what?

Mr. KVAMME. More spending in the EHS area is requested and is happening. It is roughly double of 2006 numbers from $37 to $76 million in the 2009 area. So I think that will happen.

Chairman GORDON. Did your panel discuss an appropriate level?

Mr. KVAMME. We talked about what is happening and what is the strategy behind what is happening. We have not yet completed

review of the NEHI report because it just came out in February, we looked more at what activities are in that we believe that the activities called for in that report and the subsequent EPA research strategy are appropriate things to fund, and we believe that these funding levels can support that level of research.

Chairman GORDON. So would it be fair to say that you're not satisfied with the current level, think there should be additional spending but do not want to put a specific 10 percent——

Mr. KVAMME. I think that is a fair statement. Namely, we have encouraged the increased spending in this area. Now, the particular area that we do call out that we haven't mentioned yet is in NIOSH. We believe that the workplace is the most critical area, and we do call for an acceleration of the funding in the NIOSH area.

Chairman GORDON. I know some the witnesses have a contrary view, and so what I would like to do is for each of the witnesses to respond to Mr. Kvamme's statement and see what recommendation you would have. And so we will start and just go straight down.

Mr. MURDOCK. As I said earlier, we don't know the exact appropriate level for this funding. We think 10 percent is ultimately reasonable estimate but that should be determined by strategic planning process. I think Ray David, Dr. David mentioned the National Academy's BEST study which we have also supported to figure out what that number is. I think it is also important that we continue to make the investments in some of the characterization in metrology equipment, the measurement techniques in particular for the workplace exposure. Absolutely.

Chairman GORDON. If there was a strategic review that determined that there should be a base-level funding, you would go along with that?

Mr. MURDOCK. Correct.

Chairman GORDON. Go ahead, sir.

Dr. KRAJCIK. You know, this really isn't my area of expertise, so I will pass on comments with respect to this question.

Chairman GORDON. As my mother said, if you don't have something good to say, just don't say anything at all. That is a good policy to follow. Yes, Doctor?

Dr. MAYNARD. Let me just start by saying I very much agree with Mr. Kvamme that NIOSH is one of those agencies that is doing tremendous work with virtually no dollars to do it, and that is a critical area where more investment is needed if we are going to make real progress toward developing safe nanotechnologies.

If you look at funding in general, one thing I think is indisputable. We need more money to do targeted H&S research. If we don't have more money, we will not get the answers that people need in order to make good decisions. And that means you have got to set some sort of guidelines, and you can do it one of two ways. You can either set a baseline level, say $100 million, $150 million a year which are the figures that are being recommended, or you can set it as a percentage of the overall funding for nanotechnology research. I actually think it makes it simpler to set that 10 percent level, and it is a reasonable level. Any less than that, it is really

hard to see how we are going to get the information we need in order to ensure the safety and success of these technologies.

But that funding has got to be allayed with a strategy. You cannot just look at the dollars. You have got to understand where those dollars are going, what you are going to achieve with them, and if you don't have that strategy, if you don't have that accountability, you could put $100 million, $200 million per year in this area and achieve absolutely nothing.

Chairman GORDON. Dr. David.

Dr. DAVID. I think Andrew has made some very good points, and I agree with him. I think it is very difficult to come up with an exact figure and certainly a percentage probably is the most appropriate way to approach it. Whether 10 percent is the correct number or some other percentage, I think that that is a difficult question to answer without having some external recommendation. I can tell you that within industry, companies can spend anywhere from two to five percent of their budget on R&D efforts. Pharmaceutical companies, it is 15 percent. And that simply is a reflection of the kinds of products that they are generating or what is required to determine that those products are safe for consumer uses. And so 10 percent lies somewhere in between that number and is probably as reasonable a starting point as any. But I think it is probably an excellent idea to have the National Academies come back with an actual recommendation. That seems to make the most sense to me.

Chairman GORDON. Just for your information, a part of the bill does set forth a strategic plan that we will develop for each agency. And so we hope to get that good advice, and the Academy is reviewing that plan now.

And finally, Dr. Doering.

Dr. DOERING. The semiconductor industry is certainly very interested in ESH and feels it is an important topic. The SI in fact has a committee on environmental safety and health. The industry has two R&D consortia in the United States, the Semiconductor Research Corporation as well as Semitech which co-fund a center on environmentally benign manufacturing for semiconductors at the University of Arizona. It has partner universities around the country that are part of that center as well. In addition, the International Technology Roadmap for Semiconductors, which is a very detailed document, approximately 1,000 pages of the research needs that we have for our industry, the pre-competitive needs, has a whole chapter on environmental safety and health which goes into a lot of detail on very specific things, including some in the area of nanoelectronics.

However, we haven't really done the kind of analysis that would put any particular number on what this need is. I definitely agree with most everyone else that some kind of analysis is appropriate to figure out what the plan would call for in terms of a figure, but the semiconductor industry can't suggest any number at this point.

Chairman GORDON. Thank you, and Dr. Ehlers, excuse me for running over time, and that certainly will extend to you or others that might have a threshold question like that.

Mr. EHLERS. Thank you. I timed it at 30 minutes. Seriously, a lot of good questions, good answers. But I would just like to thin

this down a bit. First of all, how does the 10 percent, singling that out, how is it going to affect the other research that is done? Mr. Kvamme, I would like to have you give me some overview of how you see this working. Let me add another question to the mix. So many different agencies and organizations involved. We are using different bookkeeping methods. How are we going to specify the 10 percent and make sure that it is fairly administered? The two questions, how do you do it and how do you administer it fairly? Secondly, what impact is that likely to have on the other research programs out there?

Mr. KVAMME. Well, let me try the second one first. That is part of the reason I inserted the graph that I did in my written statement which lists the 13 agencies that do EHS research against the five different question areas that the NEHI Report outlined as the questions. It seems to me what would have to happen, and I am no authority on governmental processes or appropriations or those kinds of things. That is not where I come from. But it seems like what you would then have to do is go down the 13 agencies and essentially say, okay, NIH, you have got to spend 6.7 percent, and NIST, you have got to spend X percent and EPA, you have got to spend 18.7 percent, et cetera. You would have to do something because they set the goals. Somebody would have to then sum the total and say, we are at 9.6 percent, we need 0.4 percent and twist NSF's arm to increase their thing a bit or something like that. I don't understand that process. That is not what I am saying. So I think that is the practical issue that I see from our analysis because you have to understand, these organizations voluntarily joined the NNI. And in the early days of our first report, we were twisting arms to get people to become part of the program to start with. And by the way, are still twisting a couple of arms which we think are important to join, so the Department of Education will come along.

So I think that is an issue relative to how you would do it, but that is in your hands. I just point that out as the practical thing.

Now, obviously the other issue that you have is the $1.5 billion supports a lot of buildings, a lot of instrumentation, a lot of other kinds of things. If you actually talk about dollars and cents going to researchers, the numbers, the $76 million that is talked about now is probably pretty close to a high single-digit number. I can't say a specific number because I don't have that breakout at my hands, but it would obviously mean that the other research would be .9 of what it has been.

But the other point that I would make that I think is very, very important to realize is that the applications research embodies EHS research in a number of areas. For example, at NIH, with our discussions with them, they have to worry about the health implications. The example I like to use is in isolation, nobody would agree to chemotherapy. It is not good for you. The plus is that it does good stuff. It eliminates cancer cells. And so you have to have that balance. Now, if you are working on a chemotherapy drug, are you working on EHS issues or are you working on cancer cures? That is a tough question to answer. And how many dollars are you allocating to the EHS piece of what you are doing versus the application piece. The way the numbers are done now, and I am sure

the way Andrew came up with $13 million he says zero, I would suspect, for the EHS piece in that research. I don't happen to agree with that assessment, and I think the $68 million in 2006 is accurate.

Mr. EHLERS. Thank you. A good example, your cancer case. I don't know if you saw the *60 Minutes* program Sunday evening where they were injecting gold nanoparticles into patients, which are selectively absorbed by the cancer cells, then using radio waves to heat them up and destroying the cells.

Mr. KVAMME. Amazing stuff.

Mr. EHLERS. It is a classic example of exactly what you were talking about. No one knew what the impact would be, and it will take considerable time to find out.

I appreciate your comments on that. Dr. Maynard, in a similar vein, you said you are not sure how these decisions are made, who decides? Dr. Maynard, you said you need leadership from the top. What do you mean by the top?

Dr. MAYNARD. Somewhere above the federal agencies themselves, probably within OSTP. And I say that in going back to your question of how could you make this 10 percent work? You can see ways you could make it work if you actually had somebody at the top level who was working with the agencies to ensure that that 10 percent funding was actually being correctly allocated across the agencies. So you have got a partnership there. But that partnership would only occur and only succeed if you had coordination and leadership from the highest possible level within government. So that is what I was thinking about in terms of leadership. It is actually making sure that somebody is pulling the process forward rather than it being pushed forward from the bottom up, in which case you have got—it is pretty much lost whether you are going to do the right thing or the wrong thing there. At least with leadership you are sure you are heading in something approximating to the right dimension.

I would also, if you will allow me, like to address the issue of what research is being done in the area of EHS issues and also whether that will impact on looking at the development of applications research and basic research.

This is a critical issue because there is no point in funding basic research and applications research if we get the risk side of things wrong. We just will not see any of that translate into viable products. So we have got to put a realistic amount of our investment, our research investment, into understanding the risks. Now, the way we do that has got to be fairly sophisticated, and Mr. Kvamme was right. My $13 million is specifically looking at questions that ask things like if you have this titanium dioxide, how am I going to use it safely. That is a question you won't find answered by looking at cancer research. It is a question you would only answer by asking very specific questions. But you have got to be more sophisticated than that. You have also got to look at how other areas of research can be applied to understanding environmental, safety, and health. And if you look at our written testimony, we actually delve into that level of sophistication. But the first and foremost thing we need to do is ask the obvious questions. How can you ensure the nanotechnologies being developed now are as safe as pos-

sible? We will not do that by trying to tag along to applications-based research. We have got to ask those specific questions, and that is what is not being done at the moment.

Mr. EHLERS. Dr. Krajcik, I just wanted to make a brief comment. Since I have spent so much of my life trying to improve math and science education, I agree with your comments. This is another example of an area where we desperately need education. I can see all kinds of horror stories getting propagated through the media about nanotechnology based on some incidents that might happen in the future, and the public just doesn't have the capability to decide. So education certainly has to be an important part of this.

One last question. Dr. David, in your testimony, you commented, we need to, you had a whole list of things we need to do. My question is, who is going to pay for it? Would you expect industry to carry this out? Do you think that we should appropriate money to do all those different things?

Dr. DAVID. I think it has to be a coalition. I think that it has to be a coalition of industry, of government-sponsored programs that support academia, or support programs within the various federal agencies. The task can be so enormous and some of the development of technology can be so daunting that I think it will require that kind of coalition in order to get the answers that we need to do, at least in a timely fashion.

Mr. EHLERS. Thank you all for your responses, your testimony. I was fascinated with this topic because it has such enormous potential, and it can change our lives in ways we can't imagine. And yet, I don't think we quite have a handle on how we are going to use it, what we are likely to find, and above all, what the dangers are. I am not one of these people who cries wolf at every corner, but I am afraid, given the history of what has happened with pesticides and other things, that the public and especially the public service agencies or entities will be waiting to jump on the first incident and try to create a Three Mile Island out of it. So we face a very ticklish job here together, and I appreciate your willingness to come here and help us understand it better.

Thank you.

Chairman GORDON. Ms. Hooley is recognized.

Ms. HOOLEY. Thank you, Mr. Chair. I, too, am very concerned about the educational piece. There are a lot of things that I am concerned about in nanotechnology. I think it also has enormous potential for the future, and I appreciate all of you being here to testify today.

When we had a hearing on this last fall, several witnesses spoke of the importance of early nanotechnology education for generating awareness and excitement about nanotechnology, particularly for young students and in fact the general public. Do you feel like this legislation accomplishes those two goals, how the general public views nanotechnology? Do you think people understand what nanotechnology is? What kind of a job do you thin we are doing with nanotechnology in our schools? Anyone on the panel that would like to answer? Don't be bashful.

Dr. KRAJCIK. I think we have a long ways to go. I think some of the fundamental ideas that underlie nanotechnology our society is pretty naíve about. Most people don't even understand where the

nano-range lies. They have a hard time distinguishing—once something gets smaller than a cell or a hair, it is undistinguishable. It is not there. So most of our children, most of our adult population, does not understand even the scale that we are talking about, let alone some of the important underlying concepts. The wonderful thing about nanotechnology is it actually brought new ideas to us. Dr. Maynard raised some of these. We now know that when you get down to the nano level, materials now get new properties.

Ms. HOOLEY. Right.

Dr. KRAJCIK. Those ideas aren't even in our science textbooks. We have science textbooks out there that don't have those ideas in them. Kids are learning that, you know, properties are always the same. They don't learn the idea that as you change scale, properties change. We have a long way to go. Our country is in serious, serious trouble when it comes to educating our children and the population with respect to nanotechnology. We have some efforts, you know. I know that the NISE network, informal science education group, is trying to do something through the museums, the Nanoscale Center for Engineering and Science is doing things, but we have a lot more that we have to be able to do because it is not pervasive in our schools, it certainly does not appear in any of our standards, and unless it gets into our standards, unless we start testing for it, we are not going to see it in schools. So we have a long ways to go if we are really going to make a difference.

If you want to speak about safety, our kids can't decide—you know, no one knows—you mentioned sunscreen. We don't know when you put this—you know, we don't see the white stuff on our face anymore. That is good, we look nice when we are at the beach and it keeps away the ultraviolet light, but we don't know if it is harmful to us, and we don't have the resources. People generally don't have the resources to make that decision. They don't even know, should I be worried about it? That's a problem. You know, we can make the decision that, okay, I am going to put this on, and it might penetrate my skin, and it might do something bad to me 30 years down the line. But people should be able to make that decision, and right now they don't have the intellectual resources to even make those kind of decisions. So I think we have a lot of work that we have to do to educate our country so we are more informed citizens.

Ms. HOOLEY. What is the one thing that we should do to in fact make the public more aware, make sure that our students are more aware of nanotechnology, of what is possible in nanotechnology, as well as what are some of the problems with nanotechnologies?

Dr. KRAJCIK. I wish I could say it was one thing. It isn't. It is a big complex system, right?

Ms. HOOLEY. You can give me two or three things, yeah.

Dr. KRAJCIK. So that is what I tried to outline very clearly. I think we really have to do sustained professional development. I think we have to change our national science education standards. They did our country good, but they are old, and they need to get revamped with new, emerging ideas in science. We have to have new instructional materials. We have to provide resources for our classrooms and we have to change our undergraduate programs,

both science courses but also our teacher preparation programs. Unless we do all these things, we are always going to be in this mess that we are in this country. We will never see ourselves back in the forefront with respect to science.

Ms. HOOLEY. For any of the panelists, how involved do you think businesses need to be in helping us reach the public in general and our educational institutions. Dr. Maynard?

Dr. MAYNARD. Very involved, but I think this is something that both business and government have got to be involved with simply because you have got the two sides of education. You have got to side of education where you are enthusing people so that they really understand and invest time and effort into nanotechnology to become the next generation of nanotechnologists. But also, you have got the side of empowering people to make informed decisions and actually engage in the process of nanotechnology and science in a broader sense. That cannot all be done by industry. Some of it has got to be done in partnership with other organizations including the government.

Ms. HOOLEY. I am just curious again——

Chairman GORDON. Ms. Hooley, if you don't mind, I am sorry. We are going to have to be a little stricter on our five minutes. We are going to have votes in 10 or 15 minutes——

Ms. HOOLEY. Thank you, Mr. Chair. I can take——

Chairman GORDON. And we will get back to you if we——

Ms. HOOLEY. I would love to just—want to have a dialogue.

Chairman GORDON. Oh, this is very important. Hopefully, this will be the start of an ongoing dialogue, both formal and informal.

Ms. Biggert, you are recognized for a crisp five minutes.

Ms. BIGGERT. Thank you, Mr. Chairman. Mr. Murdock, I have been amazed at the rapid growth of nanotech startups in my district, many of which I think you are familiar with. Many of these startups are commercializing nanotechnologies developed from basic nano research at places like Northwestern or the Center for Nano Materials at Argon. Do these start-ups face the same challenges that other small start-ups do, or are the challenges different because they are trying to build business around nanotechnology?

Mr. MURDOCK. Thank you very much. I believe that some of the challenges are the same, and some are, I'll call it more acute. These start-ups are different than software information technology based start-ups. They require more capital, and they require a much longer involvement cycles. You know, this isn't a business model that, you know when I was at Kellogg, friends could leave and start a company and scale something out in a couple years on a couple million dollars. It takes a lot longer, and it takes a lot more investment to make it go. And so we often talk about the Valley of Death, the period between, you know, the formation of the company when you start to generate revenues and cash flows, and many of these technologies that come off, whether they be argon federal laboratories where the start-ups are platform-oriented technologies. And there is a fair amount of research and development to make it robust, repeatable, scalable, and all those wonderful things before you can actually manufacture a product on it and create revenues. And that is where, you know, programs like DSBR, STTR, and the TIPR are very——

Ms. BIGGERT. So do you think that the tech transfer provisions in the draft bill will address these unique challenges?

Mr. MURDOCK. I think that they will be helpful. I think there are other—you know, I understand the SBIR reauthorization is coming up and there are some changes in that program that will also be helpful. So they certainly moved the needle in the right directly and will help the efforts to commercialize these technologies.

Ms. BIGGERT. Dr. Doering, do you think that the bill will help these challenges?

Dr. DOERING. One of the aspects that hasn't been mentioned yet with regard to that is the role of the states which is encouraged by the bill. The states obviously have a lot of interest in creating jobs locally and new business locally. And as I mentioned in my testimony, we have had some success through our consortia in working with the states, and I believe that role we need to continue to encourage.

Ms. BIGGERT. Again, Mr. Murdock, Dr. Doering, there has been a lot of talk today about what the government can and should be doing and to what degree, 10 percent more or less, to address EHS issue. What role can business play, and what role should business play to address EHS issue and help American consumers better understand the health and safety implications of nanotech technology and nano products themselves?

Mr. MURDOCK. If I could respond to that briefly, obviously businesses are responsible and accountable to make sure their products are safe. That is true for nanotechnology, that is true with everything. And you know, the member companies—it is important to understand that most of these companies are ultimately in the research phase. They are helping a prototype. Most of these technologies are not yet to the market, but they need to do the safety testing and they do based upon what is known and to ensure that those are safe.

The government, you know, we have talked about needs to develop the standards and the characterization protocols if you will to characterize these materials and the test methods to continue to evolve those based on the stated science to having our best understanding of what is in fact safe. And then industry needs to apply that.

As just a little segue, members of the NanoBusiness Alliance have invited NIOSH to their facilities, to monitor, to take measurements on the site of the air quality, to test for nanoparticulate matter in the air. Members are participating in the EPA's voluntary nanomaterials stewardship program. And so there are businesses engaging in those ways and trying to help provide the information to improve our state of knowledge.

Ms. BIGGERT. Dr. Doering, do you have anything to add?

Dr. DOERING. Yes. Speaking for the semiconductor industry, as I had mentioned earlier, we take ES&H very seriously. Most of us have very large ES&H departments within our companies that work closely with the parts of the Federal Government that help control new materials generally, whether or not they are classified as nanotechnology. As new nanomaterial come along, we take a very hard look at each one before incorporating them. We are also interested in the educational aspects on this. We primarily do that

in collaboration with each other through our trade association, the Semiconductor Industry Association which has sponsored some studies in this area. And we would be glad to work through them, and the Federal Government, in any further education a program.

Ms. BIGGERT. I guess we have gotten over the Michael Creighton book, *Prey.* Thank you very much. I yield back.

Chairman GORDON. Thank you, Ms. Biggert. Thank you. Ms. Woolsey is recognized.

Ms. WOOLSEY. Thank you, Mr. Chairman. I actually sit here today as an example of the benefits of nanotechnology. On March 5th I had huge back surgery. Here I am, back at work, have been for the last three weeks, and I have some of the brilliance of your industry implanted in my back. So thank you very much.

I agree with what you are saying. Luckily we have three Members on this committee, myself, Congressman Ehlers, and Congresswoman Biggert who are also on the Education and Labor Committees, and we will be reauthorizing, fixing, making better, *No Child Left Behind.* Therefore, I was looking out here, you are a beautiful man, you are great, but you are all white, you are all within 10- or 15-year span there. We have got to get every kid and every young person involved in the future of this country which is the new technologies, the nanotechnologies, the green technologies, that we are going to be able to keep in this country hopefully, not come up with all the good ideas in science and then give it away to the rest of the world. We have to do that.

So, I am going to tie this right back now to education and labor and *No Child Left Behind.* I would like to know from you what has your association, or what have you done yourselves in order to give us feedback on what is missing in this picture? We have got to hear it from you. Have you been participants?

Mr. KVAMME. If I could make a couple of comments, the first thing is open up. We live in a society—my parents were carpenters. Yours were farmers, the Chairman indicated. You could know what your parent did for a living. That is no longer true for many people today. I had a unique experience some years ago which I will never forget. We had our company picnic where 1,000 usually came of our 9,000 employees. We decided, hold it in the plant, have an open house, and 23,000 people showed up. People want to know what Mom and Dad do for a living, and we don't do that very well in our industries, and we don't do it because of legal concerns, insurance concerns, et cetera. We have got to change that. We have got to open up, and if there is any way legislation can do that, I highly encourage it. I am no expert in legislation, but open up our companies so people don't drive down some rows of buildings and haven't a clue what is going on in those buildings.

The second thing I would say is that when you are talking about education, you have got to be careful. This is the point I tried to make in my testimony relative to nanotechnology and technology. What we have found is people don't go into technology, they go into curing cancer, they go into doing better energy research. They go into——

Ms. WOOLSEY. Fixing my back.

Mr. KVAMME.—going to the Moon. They go into application kinds of things, and nanotechnology is a tool to that end. What we have

learned at the University of California–Berkeley where I serve on the engineering advisory board is that this center for information technology in the interest of society, CITRIS, is drawing students right and left because they see end applications for getting that double-E degree, that ME degree, whatever degree it is. They want to see societal things. I think as you introduce that to youngsters at an early age, kids are fascinated by this stuff, but they want to see, so what.

Ms. WOOLSEY. Right, they want the end result.

Mr. KVAMME. What do we got to do? So what?

Mr. MURDOCK. If I could build on that for a second, the question was asked earlier about business's role in educating the general public, and I think we are just starting to move into the second wave of nanotechnology commercialization where you're really seeing some of these, you know, very exciting, transformational applications like solar energy. There is a portfolio of companies that are really changing the cost structure of solar energy so that we are going to see, you know, meaningful new penetration of that technology. Obviously, the *60 Minutes* episode was just referenced in terms of addressing cancer. And so as more and more of these compelling applications come to market, I think it will inspire. There is an old saying, success is one percent inspiration, 99 percent perspiration. Having said that, if you don't have the inspiration first, you don't undertake the perspiration to follow. And so I think we will see more of that.

The other thing that we have said in our previous testimony on this issue is that we think it's important that people also think about education from the student's view, and not just the teacher. We absolutely agree with all of the investments that need to be made, right, in terms of teacher capability standards and all of that but to also adopt a student-centric view of the world, engage in more self-directed learning and inquiry-driven learning that is applied and helps people relate as they are educated to adult benefits in the applications associated with it.

Chairman GORDON. Thank you, Mr. Murdock, and thank you, Ms. Woolsey and we are glad that you are our example.

Ms. WOOLSEY. You like my back. Yeah, I am a good example.

Chairman GORDON. And now the temporary but not ostracized Ranking Member, Mr. Rohrabacher, is recognized for five minutes.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman. I have a little cold today. By the way, in the future, do you think nanotechnology is going to help me with my cold? Is that possible? Eating up those little bacterias or whatever that I caught from my children?

Let me say something, and you tell me if there is anybody who disagrees with this. From what I am hearing today, that everybody on the panel believes that nanotechnology has such a great, significant promise for our society, that it should be a priority for the government and society to work to develop it and to prepare for it. Would you all agree with that, it should be a priority for us? Let me tell you, the biggest impediment that I have seen to progress is that people who believe things that should be a priority for our society are unwilling to prioritize, and I will tell you that we don't need people to come here and tell us simply to spend more money

on something. Everybody will tell us to spend more money on something. What I need from you gentleman is for you to tell me exactly how important it is compared to something else that you would like us to get the funding from, because I am open to that idea. For example, fusion was a great dream. I mean, ever since I was a kid, I saw little films on fusion was going to come along. We spent billions of dollars on fusion research, and it continues today. I have asked people, you know, what is the potential of that, and they say, we will know if you just spend another billion dollars we will know what the potential is. Well, you guys seem to know what the potential of nanotechnology is. Do you think we should—is it fusion or somewhere else you can point to where we are spending a lot of money in research that this should have a priority over? Anybody on the panel is fine.

Dr. KRAJCIK. You know what? I will say that for every penny we spend on nanotechnology, we also have to spend money on education and the reason why——

Mr. ROHRABACHER. All right. Let me get to that.

Dr. KRAJCIK.—is that we cannot raise a public——

Mr. ROHRABACHER. Let me get to that. I want a priority here. I want where you are going to tell me where not to. I don't want you to go on another education speech.

Dr. KRAJCIK. I am not going to go on an education speech.

Mr. ROHRABACHER. Where is something that you want to de-fund? Nothing. Now, let me tell you something. You can come before this panel——

Mr. KVAMME. I would be happy to give you a suggestion.

Mr. ROHRABACHER. So what is it? What have you got for me?

Dr. KRAJCIK. Fusion. You can de-fund fusion.

Mr. KVAMME. By one count that we did, I think there are 220 different federal programs of some $10 million apiece for tech education K–12. There is no way that is an efficient spending of money.

Mr. ROHRABACHER. There is no way what, now?

Mr. KVAMME. There is no way that is efficient spending. You can't have 210 or 220 programs and be efficient. I would look at those and try to figure out a way how to spend half the money but do it more efficiently.

Mr. ROHRABACHER. Okay. So you don't want to de-fund, you want us to make it more efficient. Isn't there anybody that ever——

Mr. KVAMME. I will cut it in half.

Mr. ROHRABACHER. Well, can someone come here and tell me what area of research is now wasted as compared to the money that you want to spend on this? No? Okay. Well, let me tell you something. People in the scientific community should not come to Congress and tell us that they are willing to say how important something is unless they are willing to compare it to what something is less important because that doesn't mean anything. We have a limited budget. We want to do what is right by that budget. I personally would think that nanotechnology should receive a large portion of the money that we should spend or that we will save by eliminating fusion energy research because it hasn't panned out.

Back to education, to my friend who was about to talk about education, one of the problems that we have found on this committee is that sociology teachers and history teachers and English literature teachers and physical education teachers and basket weaving teachers in high school are demanding that they receive the same pay level as mathematics teachers and science teachers. Do you support a differential in pay that would permit schools to pay more money in education to mathematics and science teachers?

Dr. KRAJCIK. I think we have to have high quality math and science teachers.

Mr. ROHRABACHER. But you are not willing to say spend more? There is the other thing. There are these heavy interest groups in our society. We know the teachers unions are not going to support somebody else getting more money because it happens to be important for our society.

Dr. KRAJCIK. Well, if it takes getting good science teachers, and we need good science teachers, if it takes paying them more money, then we should pay them more money.

Mr. ROHRABACHER. Pay them more money than the other teachers?

Dr. KRAJCIK. The way we can attract our best graduates to go onto science teaching?

Mr. ROHRABACHER. Yeah.

Dr. KRAJCIK. Then I would say let us give them more money.

Mr. ROHRABACHER. It is the only way we are going to do it and it is——

Dr. KRAJCIK. If that is the case, then I think we should do it because we have a lot of really smart people, and we really need them in education.

Mr. ROHRABACHER. And we can sing their accolades all day long, but the bottom line is we want more young people to get involved, we want higher quality math and science teachers, we have got to pay them more money, and we have got to pay more money to our engineers and our scientists, rather than having them tied to sociologists and political scientists, whatever that word is.

Chairman GORDON. Thank you, Mr. Rohrabacher, and we hope you feel better. Now, Mr. Honda, we are glad that you joined us today, and you are recognized.

Mr. HONDA. Thank you, Mr. Chairman, and I think I share Mr. Rohrabacher's frustration about the constant barrage of criticism about we need to do more in education. I don't think that comes when Woolsey's question was answered. She asked what is it that you have done, rather than telling us what you think are some of the factors. And I am sure that Dr. Krajcik is a professor of education and he has spoken about the kinds of things that need to be done in the area of teacher preparation and curricula and those kinds of things. And if you are suggesting there are over 200 programs that could be cut that is in education, I would like to know how diverse those programs are before they are consolidated or cut because the last eight years, my friend, you know that education and everything else has been cut, including ATP and other things that require innovated people to be funded to—along.

So I think the idea of participating and following through with some of the ideas you do have about how to improve education

would be of great help, but being a teacher myself, I want to take this moment, Mr. Chairman, if I could and I will just tell you that all those programs and all the subject matters are important for the development of a good citizen and for development of a society that can reach its highest point. Music, performing arts, they are all embedded with science, and like nano, you know, once we understand nano, we understand that everything that functions in this world is at a nanoscale, it is just that we are just getting there. You can't take nano away from technology and expect that things are going to be the same. We suspect that with nano, you know, messing around in that whole area, would push Moore's Law another 150 years old and probably more.

And so I don't disagree that we should be putting money into basic research. I don't disagree that we should be putting money from the feds to partner with industry and—research to get beyond the gap or the value of this so they can get to commercialization. But I think that terminology or rhetoric that is so broad without detail rings hollow to me, and I appreciate this dialogue. I think the dialogue is needed to be said, and when we concern about ourselves with other countries and say they are doing better than we are, I think we better be prepared to have the details there because, you know, when people say China has 300,000 engineers, you better be prepared to say, of those how many are the kinds of engineers and technologists that we have that think new things rather than—be it civil engineers or other kinds of engineers that they need for their own development of their infrastructure in their own country.

So I think that if you can be precise, then our terminology needs to be precise, so we can solve the kinds of problems we face as a country together and then move forward without the fear of fear and invest in our own children in the proper way. And that challenge will have to go right down to how we plan our cities, how we look at the issue of equity because the way we do things with education is not equity, it is parity. Unless we are willing to change our whole assessment of what a neighborhood is, what a school is, and how we fund our children, then we are not prepared to move forward in education. And just like nanotechnology, it is an eyeopener. Things change when we get to that point. And I appreciate your work, all of your work, in the area of nano because I will have a better fishing pole as a result.

Thank you, Mr. Chairman, for letting me wax on.

Chairman GORDON. Thank you, Mr. Honda.

Mr. MURDOCK. If I could make just one quick comment? In terms of what we are doing, the nanotech companies are relatively small in the grand scheme of things, but we are starting the process of addressing this education. Several member companies that are in the instrumentation business have done R&D to create lower cost machinery so that we can get something that is viable to get into the community colleges and the classrooms so that people can have those hands-on learning experiences, one. Two, the Alliance itself is working with companies to try to set up an internship program in some of these pioneering nanotech companies so that folks can experience firsthand some of the transformational work that is taking place to lead that inspiration. It is not going to solve things,

and it is not going to do it overnight by any stretch of the imagination, but it is a start and you got to start somewhere.

Chairman GORDON. Mr. Honda, let me just—I shouldn't have to remind everyone but I will once again that last year this committee passed out on a bipartisan basis, the President signed last August the *America COMPETES Act.* The *America COMPETES Act* does a variety of things. It doubles our investment over a seven-year period in the National Science Foundation, in NIST, in the Office of Science within the Department of Energy. It also goes to the issue of our students in the math and science area, recognizing that it all starts with the teacher and that we certainly are as bright as any other country around, but you have to have teachers that not only know how to teach but also have a core knowledge within that subject area.

Just very quickly, one of the things we discovered was that 63 percent of the middle school math teachers had neither a major nor a certification to teach math. Ninety-three percent of the physical science teachers had neither a major nor certification. So no matter how good you might be in terms of your ability, you have to have a core knowledge; and that is why within the National Science Foundation, there is a program called the Noyce Scholarship Program that we scaled out that will provide scholarships for those students that want to go into math or science and education and agree to teach for five years. It will also bring back those good teachers that need more course work, a stipend for them to come in the summer. They will then be able to get their AP course, their master's, certification, whatever it might be. There will be scholarships for those folks that want to go into pure research. We really don't have to argue about this much longer. I mean, we have a plan. When Norm Augustine brought in his group that reported back on the Rising Above the Gathering Storm, I told him that they didn't bring us anything we didn't know. They just put it in a good package. We said we don't need to study it anymore, we just need to do it and that means funding it. And I have a letter here that I think it was 225 of the major industries have signed recommending that, as I say, Mr. Ehlers in a bipartisan effort and Ms. Biggert, who is not here now, are trying to do.

So hopefully we are going to be able to see that funding and from that we are going to see the realization of what we have all been talking about. Mr. Lipinski, a beneficiary of that math and science education is here and, before we hear the bells ring, is recognized.

Mr. LIPINSKI. Thank you, Mr. Chairman. I have stated many times before, I have drunk the Kool Aid on nanotechnology, but I don't want anyone to think that because I walked in here with a camera I was that excited in coming to take your pictures here. I just came from the White House with seeing the Pope there, so I just wanted to make sure I got back here as soon as I could because I wanted to—I know how important this is. I believe it is critical that we really do have an investment on behalf of the Federal Government in nanotechnology. It is really critical for our future.

In one area that I wanted to ask about, let me throw this out to whomever wants to pick up on this, I want to ask about nanoelectronics. It is certainly an important field, and I am just cu-

rious to hear a little more about what is going on in nanoelectronics, what research is being conducted, what are really the key things that the research is focusing on right now.

Dr. DOERING. I guess I will take that one. Nanoelectronics research right now is really focused on how do we replace this incumbent technology that we call CMOS for short. It is just an acronym. I won't go into the details. But it is a technology that we have used for over 30 years now. It is the workhorse of all electronics, big and small, that you see throughout the world today, and we have been miniaturizing it, or scaling it we like to say in the industry, for these 30 years and it is reaching some pretty fundamental limits in terms of what it costs per function, to try to make it smaller, what its energy efficiency is, what its speed can be, how much density of storage of information you can get with it. And so the really big, grand challenge that the industry is looking at right now in nanoelectronics is how can we find a new component, basically a new transistor which is the guts of CMOS that can take us to the next level in cost and energy efficiency and just pure performance. And so this is basically the challenge that nanoelectronics research initiative has taken up partnering so far within NSF and NIST and the Federal Government and with a number of states across the country, and we are hoping that before we have a situation where CMOS completely runs out of gas that we definitely have a new switch that can replace today's transistor.

Mr. LIPINSKI. Anyone else?

Mr. KVAMME. May I could comment. You specifically said electronics, but as you probably know, there are an awful lot of things going on in photonics where photons are replacing electrons to do certain functions, particularly in the communications sector. And today, you know, we are able now to put 80 simultaneous TV channels under a single fiber. That is largely due to what is happening from the standpoint of the constant miniaturization of what is going on in the photonics world as well, so that is another example.

Sean mentioned, and I am familiar with a company that is using nanomaterials from the standpoint of depositing solar cells, so they lower the cost dramatically. Again, not electronics, that is material science, but it is still nano and it is going to affect electronics, because it creates electrons in that particular case. So there are two other examples, photonics and energy——

Mr. LIPINSKI. Well, I am going to jump in there. You mentioned about solar. What else is going on in terms of nano research and development in regard to energy? What kind of projects are going on right now?

Mr. MURDOCK. I think there is tremendous activity and yet opportunity for more with respect to nanotechnology and energy. I think there is clear recognition now of the immense potential impact of using nanomaterials for solar energy to absorb more of the energy spectrum and to use different processes. The way we make most conventional solar cells right now is a lot like the way a Pentium chip is made, you know, polycrystalline silicon and an expensive fab, et cetera. The new approaches are using nanomaterials and doing them in more roll-to-roll processes which is more analogous to the way a newspaper is printed. So that is one big area. Another is in battery technologies. There is a lot of work with im-

proving lithium batteries, charge rates, and that but not just that. Fireflights, an Illinois company, has figured out how to essentially get the lead out of lead acid batteries and give new life to that technology which then becomes an important part of an integrated solar energy system. Fuel cells, I think if you look down almost every aspect of energy, the frontier of what is being explored, nanoscience will improve the efficiency and effectiveness of those technologies.

Chairman GORDON. Thank you, Mr. Lipinski, for blessing this hearing and now we will yield five minutes to Ms. Richardson.

Ms. RICHARDSON. Thank you, Mr. Chairman. Actually I am kind of proud to be here because I am from the home state of California, and in California, the California Nanosystems Institute was founded back in 2002; and two UC campuses who have been very engaged in that process was both UCLA and UC–Santa Barbara which I attended both of them. So this subject matter is of great interest to me as well.

I just wanted to ask one quick question, and I think it is to Dr. Maynard's office and some of the work that you have done. What can we learn from the European Union's approach to nanotechnology risk research?

Dr. MAYNARD. I don't think anybody has really got this fixed yet, but if you look at what Europe is doing, they are taking a formal strategic and systematic approach to risk-based research. So they are currently in their seventh framework research program where they are investing a lot of research across the board in nanotechnology. But they have specifically focused a number of very targeted research programs asking very specific questions, like what is the toxicity of certain nanomaterials, how do you measure exposure to nanomaterials, and half-a-dozen other projects. What they are doing is they are starting out by asking what do we need to know if we are going to make this technology succeed, and then they are asking groups of researchers to address those very specific questions. And they are putting a lot of money into it as well. But they are also doing something else which really isn't occurring in the States, and that is they are partnering between government and industry. And so every European research project that comes out also has its industrial partners, and that means not only are you leveraging money from within government and industry but you are also using the expertise that you have within those industrial partners who are developing the applications and the technologies which we hopefully are going to see being used. So that is a big difference there. And of course, I show even back as far as 2006, if you look at research which is primarily focused on understanding risks of these very, very specific questions, they are actually investing or were investing more in Europe than we were in the United States.

Ms. RICHARDSON. Thank you, Mr. Chairman.

Chairman GORDON. Thank you, Ms. Richardson. And before we close, let me also give my thanks to Ranking Member Hall for being a part of the bipartisan group that is signing the letter to the appropriators and the President asking for additional funding and supplemental for our math and science education and for the COMPETES bill. Let me also say that I think this is a good work, al-

though this is a work in process, that we have a good draft here. We welcome the good advice we have, we want to get additional advice, we want to get the best bipartisan bill that we can put together on this very important subject. And so I thank our witnesses for being a part of that today. We will leave the record open for additional Members that have questions, and with that, the witnesses are excused and the meeting is adjourned.

[Whereupon, at 11:52 a.m., the Committee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by E. Floyd Kvamme, Co-Chair, President's Council of Advisors on Science and Technology

Questions submitted by Chairman Bart Gordon

Q1. Is the President's Council of Advisors on Science and Technology (PCAST) satisfied that the NNI is adequately coordinating environmental, health and safety research internationally so as to avoid unnecessary overlap and to gain maximum benefit from the overall international research investment?

A1. Yes. As noted in PCAST's second review of the NNI: "The [National Nanotechnology Advisory Panel] NNAP has paid particular attention to EHS funding and current research efforts in this review. The panel finds that from a scientific point of view, while there is still plenty to learn, the research being funded is leading to an ever-increasing body of knowledge about EHS issues. Budgetary support for EHS has been growing at a rate well above that of the entire NNI program and, as such, the panel believes it is of the right order of magnitude to continue building knowledge of EHS issues as knowledge of the science increases. The panel does note that if expenditures of other countries in the global economy were as significant in the EHS field as those in the United States, and with ongoing, appropriately multinational communication efforts, the entire field would benefit greatly." [1]

The NNI maintains a leading role in coordinating EHS activities internationally, particularly within the Organization for Economic Cooperation and Development (OECD) and the International Standardization Organization (ISO). The U.S. (EPA) chairs the OECD Working Party on Manufactured Nanomaterials (WPMN), which is the body that is leading efforts to share EHS information and coordinate the collaborative development of information that is needed by governments and industries worldwide. The WPMN also interfaces with the broader strategic policy coordination under the Working Party on Nanotechnology, which is also chaired by the U.S. (Department of State). Also, Clayton Teague, director of the National Nanotechnology Coordinating Office (NNCO), chairs the U.S. ANSI-accredited Technical Advisory Group and heads the U.S. delegation to the ISO technical committee on nanotechnologies, which is working to develop standards for instrumentation, reference materials, test methods, and EHS practices. ISO standards often are adopted widely. PCAST endorses the NNI's continued participation and leadership in these activities, which it called for in its first report as the National Nanotechnology Advisory Panel (NNAP).

Q2. The NNTI Advisory Panel in its recent assessment of the program encourages investment in infrastructure and instrumentation under the NNI.

- *Does the Advisory Panel believe the current allocation of resources is adequate to maintain the existing facilities and provide for upgrades as needed to keep them at the leading edge of technology?*
- *Did the Advisory Panel assess whether the capabilities of the current facilities are meeting the needs of the research community in terms of accessibility and capabilities of the available instrumentation and equipment?*

A2. The NNAP assessment of the NNI is conducted at a high-level in terms of the performance of the NNI program as a whole. The panel believes that resource allocation for facility maintenance and accessibility is generally adequate and appropriate and needs to be sustained. As noted in the report, the infrastructure and instrumentation developed through the NNI is a preeminent feature of U.S. leadership in nanotechnology and constitutes a lasting legacy of the initiative. As instrumentation and methodologies for nanotechnology research continue to be developed, this structure of centers, networks, and user facilities serves to incorporate the state of the science and make it available to the maximum number of researchers in academia and industry, primarily for pre-competitive, non-proprietary research but also with an eye towards technology transfer and commercialization, as appropriate. For example, in the DOE Nanoscale Science Research Centers, user access is allocated via merit-based peer review of proposals from qualified researchers. Use of the facilities and staff assistance are provided to users free of charge, provided that the results of the research are published in the open literature. Proprietary research of merit can also be conducted at an NSRC on a full cost recovery basis. Beyond the user facilities, most NNI-funded research centers are open to collaboration with in-

[1] See *http://www.ostp.gov/galleries/PCAST/PCAST_NNAP_NNI_Assessment_2008.pdf*

dustry, and in some cases industry participation is a requirement for successful proposals (for example, NSF and NCI centers).

To date much of the investment of the NNI has been to build and resource the research facilities that now make up the 81 centers, networks, and user facilities that constitute the backbone of the NNI. In the coming years, NNI funding will shift from building to maintenance and increased support of the research these facilities were designed to carry out. Current budget levels should be adequate to support this next phase of the program.

Questions submitted by Representative Ralph M. Hall

Q1. What are the successes of the NNI over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A1. The recent PCAST report on the NNI lists examples and case studies in a variety of areas of the progress towards real-world applications resulting from the NNI. But the overarching success of the NNI has been the leadership and competitive edge that it has afforded the U.S. in the development and expansion of this novel area of technology development. Given the fact that spending in nanotechnology in Europe and Asia are approximately the same as U.S. spending, it is a credit to the NNI that America is still considered the leader across the many areas nanotechnology impacts. Thus, given the significant implications that nanotechnology development holds for nearly every industry, the additional attention and support that the NNI has brought to bear has been and remains critical for the U.S. to lead the world in capitalizing on the economic and societal benefits.

I believe the draft reauthorization presents an opportunity to support the NNI by maintaining the high-profile of nanotechnology and stressing the importance of ongoing interagency, cross-sector and international coordination. However, the current draft does appear to add unnecessary administrative burdens tending towards micro-management and that could have the unintended effect of inhibiting rather than strengthening coordination among the agencies. While there have been no systemic failures in the NNI to date, I am concerned that the onerous reporting requirements for example with nanomanufacturing and nanotechnology EHS research projects will be counterproductive and could lead to less effective collaboration. No other area of federal R&D receives such detailed scrutiny as is being proposed, and frankly the benefit of such granularity versus the cost is not clear to me. Funding that would be necessary to carry out these reporting functions could better be spent increasing public communication and education about nanotechnology as proposed in our report.

Q2. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A2. I don't feel this is a necessary addition to the legislation. The NNI previously organized its investments around "grand challenges" that included some of the proposed areas of "national importance." Programmatically, however, the organization of the NNI around Program Component Areas has been far more effective for managing and coordinating the program. Calling out particular areas of focus as "winners" by definition lowers the priority of other areas of equal (if perhaps less urgent) importance, such as fundamental basic research, which is absolutely critical to the ongoing success of our system of innovation. Furthermore adding such crosscuts over and above the PCAs may compromise the purpose of that structure for managing and coordinating the NNI.

Questions submitted by Representative Daniel Lipinski

Q1. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this fact in their products, for fear of public backlash. I understand their concerns, as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the held of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give us some examples of what other countries are doing to inform and educate their people?

A1. Yes. Strengthening our public outreach and communication efforts is essential to avoid the drawbacks of hyping both anticipated benefits and feared risks by

grounding the public dialogue in actual science and fact. As noted in our report, PCAST remains concerned that the economic and societal benefits of nanotechnology are being overlooked or minimized by the emphasis on uncertainties and speculation that is unconstrained by actual, realistic exposure and hazard assessment.

I'm not positioned to speak in anything other than broad terms with respect to the outreach and public engagement efforts of other countries on nanotechnology, but it certainly will serve our efforts for the NNI to continue engaging with other countries, as it has with the Working Party on Nanotechnology of the OECD, in international workshops and programs aimed at improving communication and broad stakeholder engagement by exchanging best practices and evaluating various policies in societal context.

Q2. Nanoelectronics is an area within the field of nanotechnology that is certainly important, and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted thus far from this research? Approximately how much funding is currently devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A2. The industrial sector has historically taken the lead in collaborative, pre-competitive work on developing the fundamental technologies that are fundamental to electronics, including circuit component and chip design that looks beyond the current state-of-the-art. NNI continues to facilitate this work through its industrial liaison working group which is working with the semiconductor industry and through funding of collaborative, cross-sector programs like the model Nanoelectronics Research Initiative (NRI; *nri.src.org*). NSF and NIST have formed public-private partnerships with the NRI to support ground-breaking nanoelectronics R&D. Both agencies and the industry members of the NRI each provide funding to support research towards that target, conducted through university-based centers.

The NNI tracks annual funding by Program Component Area rather than application area, but a rough estimate by the National Nanotechnology Coordinating Office of funding for nanoelectronics (including nanomagnetics and nanophotonics for processing, storage, and/or communications devices, which are difficult to separate out) across the NNI is approximately $100 million. PCAST did not formally assess the adequacy of funding for particular application areas within the NNI, but its broader assessment of technology transfer and commercialization through the NNI was positive, noting that the NNI plays a key role in surmounting the barriers to nanotechnology innovation and commercial application by supporting both basic and targeted research, developing and maintaining critical infrastructure, and training researchers with interdisciplinary capabilities to capture the revolutionary potential of nanotechnology.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Sean Murdock, Executive Director, NanoBusiness Alliance

Questions submitted by Chairman Bart Gordon

Q1. Is there a need to expand the availability of nanotechnology user facilities that would be relevant to industry's needs? If so, would the NSF Industry-University Research Centers model be a viable mechanism for expanding the number and diversity of nanotechnology user facilities? Under such a model, federal funding would support the initial start-up costs, administration, and staffing needs of the user facility, while industry would provide the bulk of funding through user fees for use of the facilities.

A1. There is a need to expand the availability of nanotechnology user facilities that are relevant to industry's needs, and the *National Nanotechnology Initiative Amendments Act of 2008* will help address that need. The NSF Industry-University Research Centers model is a viable mechanism, provided that nanotechnology companies are made aware of its availability and that administrative requirements (and IP policies) are not onerous for companies seeking to participate. Furthermore, it is critical that the user fees are based upon the marginal cost of provisioning services (plus a markup) so that general university (as opposed to true facility) overheads are not built into the user fees. Otherwise, overhead costs often become significant and create a disincentive for industry use.

Q2. To what extent are nanotechnology businesses engaged in educational outreach activities with high school students or post-secondary students? Do your companies sponsor activities at informal science institutions?

A2. Nanotechnology businesses are in many cases engaged in educational outreach activities with high school and post-secondary students. Although most nanotechnology businesses are small businesses that lack the resources to support substantial programs, a number of companies have established internships for high school or college students. The NanoBusiness Alliance itself has an internship program that places talented students with leading nanotechnology companies. In addition, nanotechnology tools manufacturers are designing relatively inexpensive, user-friendly tools for classroom use.

Questions submitted by Representative Ralph M. Hall

Q1. What are the successes of the NNI over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A1. The NNI has been extraordinarily successful over the past five years in accomplishing its central task of coordinating and accelerating federal nanotechnology research and development. The *National Nanotechnology Initiative Amendments Act of 2008* preserves the elements of the NNI's structure that led to those successes. The NNI has been less successful at the admittedly difficult task of setting and environmental, health, and safety (EHS) research agenda, and the bill takes steps to address that issue. The Alliance does not recommend terminating any portion of the NNI at this point.

Q2. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A2. The Alliance believes it is important that the Federal Government not pick winners and losers in the marketplace. Foreign countries are focusing their investments and supporting companies directly to help establish nanotechnology and to compete with the United States. The Alliance argued for the inclusion of support for translational nanotechnology research in areas on national importance to level the playing field, but has recommended keeping these areas broad so as to avoid picking winners and losers. Furthermore, funding in these areas of national importance will take place on a competitive basis, so the actual winners and losers will depend upon market competitiveness.

Questions submitted by Representative Daniel Lipinski

Q1. Sean, you mentioned in your testimony that we should focus our efforts on goal-oriented research in areas of national importance. It seems to me that the Nation's Centers on Nanotechnology are critical to solving the grand challenges of our time, such as those we face on the environment and energy. Can you give us some examples of the products that have resulted from the research being conducted at these Centers? And in what other areas do you suggest we focus our efforts?

A1. There are important products beginning to emerge from these centers. A case study that may be of particular interest to Congressman Lipinski because of its proximity to his district is Northwestern University's Nanoscale Science and Engineering Center (NSEC). Nanosphere, which is based in Northbrook, Illinois has recently received approval for a molecular diagnostic test for susceptibility to warfarin, a blood thinner used for stroke victims in emergency room situations. Because the test will provide information on genetic susceptibility in real time, it will save lives. NanoInk is commercializing NanoEncryption™ Technology based upon dip pen nanolithography developed by Chad Mirkin at Northwestern. The technology makes it possible to secure the Nation's pharmaceutical drug supply by encoding a nanoscale mark on each pill that is manufactured, which technology will protect patient safety and reduce the opportunity for criminals and terrorists to sell counterfeit pharmaceuticals. Many more products are on the way from Northwestern's center and others throughout the Nation. We are just beginning to see the return on our nation's investment in nanoscience centers of excellence.

The Alliance supports the areas of national importance listed in the bill. In general, we believe that the United States has comparative advantages in most of the areas that make nanotechnology a benefit from an EHS perspective: cleaner energy, better health care, improved water and air quality, and so on—as well as nanoelectronics.

Q2. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this fact in their products, for fear of public backlash. I understand their concerns, as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the field of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give us some examples of what other countries are doing to inform and educate their people?

A2. The general public still does not have a solid understanding of nanotechnology, despite the best efforts of the Alliance, its members, and countless educational institutions throughout the country. The bill takes some steps to help address this situation, which is important because the public's lack of a clear understanding of nanotechnology is one of the greatest risks that the nanobusiness community faces. International cooperation is critically important, especially in the area of standards development—but when it comes to educating the public, I believe that we need to be educating Europe rather than asking for their help to educate us. It seems that not a month goes by without an over-hyped scare story from Europe, or another argument for the precautionary principle in the EU. Coverage of and education about nanotechnology in the United States is much more balanced and takes into account the very real benefits of nanotechnology even as it speculates about risks.

Q3. Nanoelectronics is an area within the field of nanotechnology that is certainly important, and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted thus far from this research? Approximately how much funding is currently devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A3. Nanoelectronics research provides a great example of the leverage we as a nation can get when we focus on goal oriented research. The Semiconductor Industry Association has established a Nanoelectronics Research Initiative which has teamed with National Science Foundation and NIST to help shape and provide industry funding for critical beyond CMOS nanoelectronics research.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Joseph S. Krajcik, Professor of Science Education; Associate Dean of Research, University of Michigan

Questions submitted by Representative Ralph M. Hall

Q1. What are the successes of the NNI over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A1. I will limit my responses to my area of expertise: science education. Two bright areas resulted from the NNI over the past five years: The Nanoscale Informal Science Education (NISE) Network and the National Center for Teaching and Learning Nanoscale Science and Engineering (NCLT). (Note: I am a co-principal investigator of NCLT and this relationship needs to be taken into consideration when reading my remarks.)

NISE, funded through the National Science Foundation, 2005, is designed to bring the education and research communities together in an effort to inform the public about nanoscience. In particular the NISE Network:

- creates new methods and approaches to communicate the work of nanoscale scientists and engineers to the public;
- informs the public about the advances in the scientific research; and
- captures the imagination of youth who may choose careers in nanoscale science and engineering.

NISE has done much to bring nanoscale science to the public and I would encourage continual funding of the effort. Through a new web site, the NISE Network Resource Center (*http://www.nisenet.org*), teachers and the public can access a vast collection of educational resources and join in this creative community effort. For teachers, students, or anyone interested in nanoscience and the many potential nanotechnology applications, the web site's content includes study materials, academic approaches, collections of graphics, a newsletter, links to other institutions working in the field, and much more. To learn more about the NISE network see: *http://www.nisenet.org/project/what.html.*

NCLT, funded by the National Science Foundation in 2004, was established to build national capacity in nanoscale science and engineering education as well as explore how to how to improve the teaching and learning of nanoscience in grades seven through college. Housed at Northwestern University, NCLT collaborates with scientists and educators at the following research institutions: University of Michigan, Purdue University, University of Illinois at Chicago, University of Illinois at Urbana-Champaign, Argonne National Laboratory, Alabama A&M University, Fisk University, Hampton University, Morehouse College, and University of Texas at El Paso. Through the educational research produced by NCLT researchers, important ideas related to the teaching and learning of nanoscience are being uncovered.

Through its web portal NCLT, *http://nclt.us/,* offers a variety of educational resources to help teachers and science educators with nanotechnology-related concepts, simulations, and activities for the classroom that include:

- Educational materials for science teachers and students in grades 7–12, college and university students and faculty, researchers, and post-doc students, covering information on Nano Courses & Units in engineering, physics, materials science, chemistry, and education.
- Seminars to advance education initiatives.
- Learning Research and Methods, a collection of papers, presentations and resources to promote the best teaching practices and methodologies.
- Nanoconcepts and Applications, instructional materials focusing on the key ideas in nanoscale science and engineering.
- NSEE Resources and Calendar of Events for nanoscale science and engineering education.
- NSEE News and Network and a Glossary.

Both NISE and NCLT have done much to advance learning of nanoscience in formal and informal settings. As such, I would encourage that these aspects of The *National Nanotechnology Initiative Amendments Act of 2008* be preserved. As in science, progress in education will only be made if continual support is provided for projects and centers that focus on important national goals and that have proven track records of collaborative partnerships that improve the teaching and learning

of nanoscience. As stated in my written testimony, advances in nanoscience require a commensurate response from the educational community to prepare our youth.

The NNI also supports various national nanotechnology centers such as the Materials Research Science and Engineers Centers and the National Nanotechnology Infrastructure Network that have an educational outreach component within them. Although I know more about the activities NNIN education activities that go on at the University of Michigan, I know little about other NNIM and MRSEC education activities. I know that the NNIN education activities bring new emerging activities to students such as "nanocamps" that allow 6th–12th grade students opportunities to explore clean rooms. Such activities have very high interest to many learners. As such, I would encourage continual funding of these efforts. However, I would also encourage that such centers partner with experts in science education and learning science so that the engaging activities can be better incorporated into the structure of the school curriculum. Building such connections between motivating activities and classroom curriculum is critical to promote learning.

Q2. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A2. There is no argument that STEM education in this country is in a crisis. U.S. schools are failing to prepare students to live in a technological advanced society. This is particularly true in our large urban districts. If we can turn this crisis around, and we must, then we all win. Our economy will improve and perhaps more importantly our children will have the standard of living and the quality of life that we achieved. However, unless we can focus on improving education, our children and their children will not have the quality of life that we find valuable. Congress has to provide the direction of our national priorities.

I would also argue that advances in science and technology are blurring the lines between the individual scientific disciplines that allow for advances in science and technology. As science becomes more interdisciplinary, we can no longer rely on the traditional ways of teaching science as a set of well-understood, clearly depicted, stand-alone disciplines. If we do so, we are not preparing our students for the scientific enterprise they will experience in the work force. Yet, both at the K–12 level and 13–16 level, we continue to teach in non-interdisciplinary fashion and without stressing how important ideas cut across disciplinary boundaries.

Q3. You state in your testimony that "Unfortunately, the current education system is failing to produce a populace scientifically literate enough to understand the scientific advances of nanoscience." Couldn't the same be said for biology, physics, chemistry, computer science, or many other scientific disciplines? If current science curricula concentrates on covering too much content, as you argue, and yet you also recommend that all students need to know more about nanoscience, then what content do you propose replacing?

A3. I agree that the U.S. educational system is failing to produce a populace that is scientifically literate to understand the advances in all fields of science and not just nanoscience. What we are failing to do as a Nation is help students understand the "core" or "big" ideas of science that are essential in helping all learners understand advances across fields.

The U.S. science curriculum concentrates on covering too much content without focusing on developing deep, meaningful understanding that learners will need to grasp the central ideas of science and new areas or that they will need to make personal and professional decisions in their lives. Research has shown that students lack fundamental understanding of science in such areas as the structure of matter, forces, and properties of matter. These fundamental ideas are essential to understanding a number of areas of science.

As I tried to argue in my written testimony, a path to improve the U.S. educational system requires the development of new standards. New standards that focus on the big ideas of science and cut across disciplines, and other knowledge essential for the 21st century need to be developed and adapted by schools. Important ideas in nanoscience are not currently incorporated or stressed in the national standards. Nanoscience education introduces students to emerging ideas of science and supports understanding of the interconnections between the traditional scientific domains by providing compelling, real-world interdisciplinary examples of science in action.

The national science education standards need renovation because there are too many standards. We will need to make some tough choices in that all content cannot be covered. We know from successes in other countries and from research studies, that attempting to cover too many ideas lead students to develop superficial

knowledge that they cannot use to solve problems, make decisions, and understand phenomena. Hence, our national science education standards need reworking, updating and consolidating.

Rather than focusing on covering too many ideas, our nation needs a long-term developmental approach to learning science that focuses on the big ideas of science we most care about and takes into consideration learners' prior knowledge and how ideas build upon each other. Big ideas provide a framework for thinking about the long-term development of student understanding and they facilitate learners to understand a variety of different phenomena within and across science disciplines. If we have a developmental approach starting in kindergarten through 12th grade, learners will come away with a level of understanding that will allow them to pursue STEM careers, see the importance of science in their lives, and use science to make decisions. If our nation takes a developmental approach to the standards that emphasize how ideas build upon each other, it will allow curriculum designers to develop coherent curriculum materials.

Let me provide just one short example. The atomic and kinetic theories are the foundation for understanding the structure, properties and behavior of matter. Together, they can explain an enormous number of phenomena across a variety of disciplines. At the same time, understanding of these ideas is essential for building an understanding about the structure, properties and behavior of matter at the nanoscale. A development approach focusing on how these ideas build over time will allow students to build the rich understanding that is needed to understand the science of today and tomorrow and will facilitate the interdisciplinary connections that students need to understand nanoscience and other emerging science (Stevens, Sutherland, Shank & Krajcik, 2008). I encourage the Committee to read Steven, Sutherland, Shank and Krajcik for more in-depth ideas in this area. I also encourage the Committee to read *Taking Science to School,* by Duschl, Schweinger, and Shouse (2007).

Questions submitted by Representative Daniel Lipinski

Q1. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this fact in their products, for fear of public backlash. I understand their concerns, as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the field of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give some examples of what other countries are doing to inform and educate their people?

A1. An informed citizenship is critical in a democratic society. I am appalled by the notion that information is being kept from the public because of fear of public backlash. To be a free, democratic and competitive country, our goal, as a nation, must be to provide a solid education for ALL so that information is freely available to the public and that they requisite skills to interpret and apply the information to their lives. Given that nanoscience impacts virtually every sector of our economy and our daily lives by enabling promising new materials and applications across many fields, I would argue that the legislation does not go far enough to enhance public awareness and education in the field nanotechnology.

There are some bright spots in nanoeducation in this country. Two of them I have discussed above—the NISE Network and the NCLT. NISE focuses primarily on informal education and NCLT on formal education. Information regarding NISE is available at *http://www.nisenet.org* and for NCLT at *http://www.nclt.us/*. That said, I believe the U.S. formal and informal education systems could learn through international cooperation with other countries that are working to inform the public regarding nanoscience. The NCLT web site has information on what other countries are doing.

Below I will summarize some of the information about what other countries are doing. See *http://www.nclt.us/ncplthome/major_nano_initiatives.html* for further information.

a. Taiwan is an international leader in nanotechnology education, with formal and informal education initiatives for all levels and an especially strong K–12 program. The National Science Council, Taiwan, R.O.C., established a nanotechnology program for K–12 teachers in order to provide educational opportunities on the cutting edge of advanced technology.

b. NanoForum, established with funding from the European Commission, serves as the "European Nanotechnology Gateway," providing articles,

events, funding information, research databases, and other services to support nanotechnology research, development, and education.

c. Nanotechnology Researchers Network Center of Japan (NanoNet), launched in 2007, introduces various information on top nanotechnology through its web site and an e-mail newsletter. The web site has a major section that is tailored to children and includes games that can help children learn about nanoscience.

Q2. Nanoelectronics is an area within the field of nanotechnology that is certainly important and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted this far from this research? Approximately how much funding is currently devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A2. This is not my area of research, so I do not feel qualified to respond.

References:

Duschl, R.A., Schweingruber, H.A., Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K–8.* Washington, D.C.: National Academies Press.

Stevens, S. Sutherland, L., Shank, P., Krajcik, J. (2008). *Big Ideas in NanoScience. http://www.hice.org/projects/nano/index.html.*

ANSWERS TO POST-HEARING QUESTIONS

Responses by Andrew D. Maynard, Chief Science Advisor, Project on Emerging Nanotechnologies, Woodrow Wilson International Center for Scholars

Questions submitted by Representative Ralph M. Hall

Q1. What are the successes of the NNI over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A1. Over the past five years, the NNI has stimulated innovative research enabling the United States to lead the world in nanotech research and development. It is a testament to this success that other countries are emulating the U.S. model. The NNI has also effectively fostered a high degree of coordination across a large number of agencies and departments, resulting in multi-disciplinary research that is essential for supporting and sustaining successful nanotechnologies.

In my opinion, it is clear that the NNI has led to greater cross-government coordination for science and technology than with any previous initiative, and for this, its instigators, supporters and implementers should be congratulated. But this does not mean that there is cause for complacency. While the achievements of the NNI are apparent, there are areas that are in desperate need of improvement:

- *The lack of a robust environmental, health and safety (EHS) research strategy has led to insufficient funding and leadership to effectively study and combat-possible EHS issues associated with nanotechnologies.* From my assessment of what is needed to underpin the long-term success of emerging nanotechnologies and provide industry with the confidence to invest in this area, a minimum 10 percent of the NNI budget should be directed towards EHS research. But this funding must be directed within a top-down strategy with clearly defined goals, and a plan for achieving them. At an absolute minimum, steps are needed to ensure sufficient funds are available to regulatory and research agencies in support of strategic activities constituting the Environmental, Health, and Safety program component area, or any successor program component area.
- *Full and transparent stakeholder involvement in the NNI is lacking.* This is most apparent in the development of the EHS R&D strategy. While there are some interactions between the NNI and stakeholders representing industry, labor, academia, citizens and the international community, more is needed to ensure that government-funded research and development remains relevant. For instance, the recent NNI EHS R&D strategy involved limited stakeholder input at the review stage, but not as it was being developed. Had a wider community been engaged at an earlier stage, it is likely that the strategy would be more focused on addressing real priority needs, rather than justifying past actions.
- *The NNI has struggled to support the translation of research into viable commercial products.* In many ways, this is understandable, as the initial phase of the NNI was focused on expanding the nanotechnology knowledge base through research. But as nanotechnology commercialization becomes an increasingly pressing challenge, a change of emphasis and mode of action is needed.
- *The NNI has failed to educate and engage citizens effectively.* This is critical on three counts: First, as new nanotechnology-based products enter the market in increasing numbers, consumers need the ability and information to make informed decisions on these products. Second, the future of nanotechnology will depend on people in all walks of life being enthused and inspired by the technology and what it can do—leading to the next generation of nano-scientists and nano-engineers. And thirdly, I believe successful science and technology in the twenty first century—including nanotechnology—will depend on all citizens having an opportunity to contribute to the direction and use of future research. This will require education (both formal and informal) to help people assess the value and challenges of new science and technology, and mechanisms for giving people a voice as new science directions are explored and new technologies are developed. According to public research polls conducted by the Project on Emerging

Nanotechnologies (PEN),[1] the public still knows very little about nanotechnology.

Q2. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A2. Addressing major challenges facing society needs leadership from the top. Nanotechnology is an enabling technology and will provide the tools to solve many of society's pressing problems—including global climate change, pollution and disease. When resources are limited, strategic direction from the top is essential to ensure progress is made towards safe and successful technological solutions. This is not choosing winners and losers; but rather foreseeing innovations and technologies that the United States can lead the world in. Without Congress leading the way, we risk jeopardizing nanotechnology innovation in the U.S. and lessening the chance of nanotechnology R&D stimulating the economy, creating jobs, solving major environmental challenges and improving quality of life. Other economies around the world are unlikely to hold back on strategic R&D leadership where there are clear social and economic advantages, and for the U.S. to do so would place the country at a disadvantage.

Questions submitted by Representative Daniel Lipinski

Q1. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this fact in their products, for fear of public backlash. I understand their concerns, as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the field of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give us some examples of what countries are doing to inform and educate their people?

A1. There is currently not enough being done to inform and educate members of the public on how nanotechnology will impact their lives, or to engage them in how future technologies are developed and used. And while the draft *National Nanotechnology Initiative Amendment Act of 2008* addresses K though 12 and college education, it is lacking when it comes to supporting broader educational issues. Formal education in terms of training future scientists is getting better and will improve further through various Science, Technology, Engineering and Mathematics Education initiatives. But empowering everyday people to make informed decisions about the technologies that affect their lives is critically lacking.

Transparency is vital to the success of nanotechnology; not only regarding government investment, actions and plans, but also in providing people with information on how nanotechnology is being used in products and processes that affect their daily lives. Opinion polls—including those conducted by the Project on Emerging Nanotechnologies[2]—show that people want to be informed, and a perception of being kept in the dark seriously undermines confidence in new technologies and their promoters.

Yet to be useful, transparency must be linked to an ability to understand and use information effectively. And this places a bright spotlight on education—especially informal education, which takes place outside the classroom.

Effective nanotechnology education means meeting people where they are at—whether through popular culture, the media or museums and exhibits. Government and industry need to invest much more in informal education if an awareness and understanding of nanotechnology is to diffuse through society. And this needs to be an investment in education, rather than academic studies of how to educate.

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[1] Awareness of and Attitudes Toward Nanotechnology and Federal Regulatory Agencies (2007), Peter D. Hart Research Associates for The Project on Emerging Nanotechnologies. *www.nanotechproject.org/process/assets/files/5888/hart_presentation_2007analysis.pdf*

[2] Kahan, D., Slovic, P. Braman, D., Gastil, J., Cohen, G. 2007. Nanotechnology Risk Perceptions: The Influence of Affect and Values. Conducted by the Cultural Cognition Project at Yale Law School for the Project on Emerging Nanotechnologies. Available at: *http://www.nanotechproject.org/mint/pepper/tillkruess/downloads/tracker.php?uri=http%3A//www.nanotechproject.org/process/assets/files/2710/164_nanotechriskperceptions_dankahan.pdf.* Also see: Awareness of and Attitudes Toward Nanotechnology and Federal Regulatory Agencies (2007), Peter D. Hart Research Associates for The Project on Emerging Nanotechnologies. Available at: *www.nanotechproject.org/process/assets/files/5888/hart_presentation_2007analysis.pdf*

But beyond education comes engagement—you cannot give people the tools to understand new technologies, but then deny them a voice in the decision-making process. Effective engagement efforts are currently lacking in the NNI, and in the draft bill.

In contrast to the U.S., the European Union has clear goals for educating and engaging citizens. In its policy for Nanosciences and Nanotechnologies,[3] the European Union recognizes "the need to devote due attention to the societal aspects of nanotechnology" and sets forth the following:

a. calls upon the Member States to pursue an open and proactive approach to governance in nanotechnology R&D to ensure public awareness and confidence;

b. encourages a dialogue with EU citizens/consumers to promote informed judgment on nanotechnology R&D based on impartial information and the exchange of ideas;

c. reaffirms its commitment to ethical principals in order to ensure that R&D in nanotechnology is carried out in a responsible and transparent manner.

Q2. Nanoelectronics is an area within the field of nanotechnology that is certainly important, and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted thus far from this research? Approximately how much funding is currently devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A2. This is not my primary area of expertise, and I would defer to my fellow panel member, Dr. Robert Doering, for a detailed answer to the question. But I would like to make a couple of observations:

Complementary Metal Oxide Semiconductor technology—commonly referred to as CMOS—is the foundation of modern electronics. Yet while the processing power of semiconductor chips continues to double almost every two years, it will soon hit a brick wall—the point where physical laws prevent conventional CMOS-based electronics getting any smaller or faster. Nanotechnology is a key technology for overcoming this barrier; enabling existing technologies to be used in innovative ways; generating new electronics technologies to replace CMOS, and even discovering alternatives to using electrons—such as photons, in the area of photonics.

The timescale between innovation and implementation is long in the electronics business however, and it is the research of today that will provide technological solutions of the next decade. As a result, there is an urgent need for extensive research now into new nanotechnology-based "electronics" or "nanoelectronics" if we want to continue the current trend of faster, smaller, more efficient processors. Industry is acutely aware of this challenge, and is investing considerable resources in supporting innovative research. But support from government is also needed, if America is to remain at the forefront of the nanoelectronics revolution.

Question submitted by Representative Adrian Smith

Q1. At the University of Nebraska Medical Center (UNMC), researchers are studying nanomedicine, which merges engineering science with pharmaceutical and medical sciences, to translate advances in nanotechnology research into clinical practice. UNMC researchers have been recognized nationally and internationally for developing tiny particles, called nanomaterials, which are put in the body to deliver drugs precisely to diseased cells, to treat conditions such as cancer, Parkinson's and Alzheimer's diseases, and others. This unique nanotechnology delivers drugs directly to diseased areas or tumors, which maximizes clinical benefits, while limiting negative side effects. The use of nanoscale technologies to design drug delivery systems is a rapidly developing area of biomedical research that promises breakthrough advances in therapeutics and diagnostics. It is clear from the medical research in Nebraska that the development of medical nanotechnology is moving quickly toward human clinical trials. At the October hearing on this subject, according to the briefing document, "there were concern that the interagency planning for and implementation of the environment, health and safety research component of NNI was not moving with the urgency it deserved." Development of nanotechnology is breakthrough technology with the

[3] EU Policy for Nanosciences and Nanotechnologies. 2004. European Commission. *http://ec.europa.eu/nanotechnology/pdf/eu_nano_policy_2004-07.pdf*

ability to profoundly improve the treatment and cure of disease. This legislation intends to strengthen the planning and implementation of the environment, health and safety component and increase the emphasis on commercialization of nanotechnology research results. To accomplish that, guidelines will be necessary. What progress is being made to establish safety guidelines for the use of nanotechnology to deliver medication when it is ready for the marketplace and adopted as standard of care by health care professionals?

A1. New nanotechnology-enabled drugs push the boundaries of our understanding and abilities. They penetrate to places in the body and interact with cells and tissues in new ways, because of their nanoscale size and structure. They can be designed to carry out many functions; detecting and diagnosing disease, as well as treating it. And they often blur the boundaries between distinct regulatory classes of products. These characteristics offer the promise of innovative new medical treatments. But they also raise new concerns over possible health implications.

Some progress is being made to address the challenge of developing safe and beneficial nanotechnology-based drugs. For instance, the FDA, in partnership with National Cancer Institute and the National Institute for Standards and Technology, has set up the Nanoparticle Characterization Laboratory to help evaluate the safety of developmental nano-drugs. But the pace of development and the increasingly sophisticated nature of these medications are stretching the ability of researchers and regulators to apply conventional understanding to these unconventional products.

The United States cannot afford to *not* develop drugs enhanced with nanotechnology. They promise to be more effective treatments with fewer side effects; and have the ability to treat previously untreatable diseases. But if we lose focus and don't get the environment, health and safety aspects of these products of nanotechnology right, those benefits will be lost. This is why adequate funding, along with strong leadership and a robust risk research strategy, are essential to ensuring nanotech-enabled drugs don't lead to unanticipated harm. This is a small price to pay in order to reap the enormous benefits nanotechnology could provide.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Raymond David, Manager of Toxicology for Industrial Chemicals, BASF Corporation

Questions submitted by Chairman Bart Gordon

Q1. Is there a need to expand the availability of nanotechnology user facilities that would be relevant to industry's needs? If so, would the NNI Industry-University Research Centers model be a viable mechanism for expanding the number and diversity of nanotechnology user facilities? Under such a model, federal funding would support the initial start-up costs, administration, and staffing needs of the user facility, while industry would provide the bulk of funding through user fees for use of the facilities.

A1. The Panel believes that there may be a lack of awareness of user facilities available to the nanotechnology community, which may lead to their under-utilization by industry. Furthermore, some of the centers have very focused missions, which do not allow for projects outside of their scope. For example, the Nanomaterials Characterization Laboratory focuses on medical applications of nanomaterials and the laboratory will not accept a project outside of that scope. A partnership approach similar to the NSF Industry-University Research Centers may be a more viable model, and would certainly be more flexible. It would also allow SME nanotechnology companies to obtain the services they need without the extensive capital investment needed for instrumentation.

Q2. To what extent are nanotechnology businesses engaged in educational outreach activities with high school students or post-secondary students? Do your companies sponsor activities at informal science institutions?

A2. Panel members experience indicates that outreach programs are most successful through large associations or scientific societies. For example, the Society of Toxicology has an outreach program to elementary and secondary schools called "Paracelsus goes to school." It is well organized and successful in educating students about toxicology, dose-response, and specific hazards to avoid. The NNI could establish a similarly structured program. The companies of the ACC Nanotechnology Panel also sponsor informational events for targeted audiences, maintain a web page that provides information to the public, and engage in extensive outreach to various constituencies to provide information pertinent to the safe and responsible development of nanotechnology. Panel member companies would welcome the opportunity to provide input and experts for informal scientific sessions with students of all ages.

Questions submitted by Representative Ralph M. Hall

Q1. It is our understanding that responsible manufacturers and users of nanomaterials, including presumably some ACC members, are generating information about their properties that could be relevant to understanding their biological and environmental behavior. How can that information be shared so that risk assessment and risk management in general can be improved and so that developers can design more benign materials and avoid pitfalls?

A1. Scientists from industry, academia, and government research facilities are engaged in developing data on the hazards of nanomaterials, and the physical/chemical properties that are associated with those hazards. Once these data are published in scientific journals, there are several public databases that capture and catalogue the information for others to use in assessing the risks of exposure. Unfortunately, the Nanotechnology Panel believes that some of the published data fail to accurately characterize the properties of the particles tested. International efforts within the OECD, ISO and private efforts to heighten awareness for the need for accurate characterization will help sort these issues out. In addition, EPA's Nanoscale Materials Stewardship Program (NMSP) is designed to collect information for EPA's use to develop risk assessment and management profiles. Additional information will facilitate EPA's ability to characterize nanoscale materials accurately. The Panel members will be participating in this program.

Q2. What are the successes of the NNl over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A2. A key NNI success has been providing a mechanism for information exchange between government agencies regarding nanotechnology. It appears that the enthusiasm for this is high as indicated by the broad participation of agencies. Participating agencies include those conducting research as well as regulatory bodies showing an awareness of the linkage between these normally separate approaches. The main function of the NNI is to promote the development of nanotechnology and this appears to have been a great success. A perceived weakness, however, has been an incommensurate level of commitment of NNI agency resources to issues regarding society and safety. Many view government agencies as an "honest broker" thus they have a unique role and contribution to make to help ensure that nanotechnology undergoes responsible development. A commitment of the NNI for a significant increase in member agency funding over present levels to address EHS issues will greatly contribute to its future success. A target of 8–15 percent of overall NNI spending should be considered to fund EHS activities and is consistent with Goal 4 of the NNI Strategic Plan.

Q3. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A3. Neither Congress nor the NNl agencies should be viewed as picking winners or losers. The breadth of activities and interests of the member agencies are sufficient to encompass many of the activities for which funding will be sought. However, it is appropriate for Congress to identify and focus attention on areas that it believes will have particularly beneficial impacts.

Questions submitted by Representative Daniel Lipinski

Q1. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this fact in their products, for fear of public backlash. I understand their concerns, as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the field of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give us some examples of what other countries are doing to inform and educate their people?

A1. The NNI amendments do not specifically address education of the general public. This could be addressed in any number of ways not the least of which are targeted informational programs through the Public Broadcasting Service, Public Service Announcements, or other media. The NNI amendments do provide for the education of secondary teachers and students, which in turn will lead to better educating the general public. The concern expressed in the question may be a symptom of an overall lack of public understanding about the many positive contributions to society and safety made through the use of science and engineering. The Act does provide for funding to be available for projects in subcategories of education in formal (e.g., schools, colleges, universities) and informal settings (e.g., museums and exhibits) as well as for public outreach and societal issues. The Department of Education is a new NNI agency and this could be an area where DOEd can make strong contributions to the success of the NNI since education is its primary mission. In addition, the NNI amendments could include scholarship funding for graduate level courses to further train scientists in the various disciplines associated with nanotechnology.

Q2. Nanoelectronics is an area within the field of nanotechnology that is certainly important, and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted thus far from this research? Approximately how much funding is devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A2. The chemical industry is a key supplier of materials to the electronics industry. While the specific question is best directed to those who are in the nanoelectronics industry we are pleased to make essential contributions to their success. SEMI represents the semiconductor producers and may be able to provide additional information.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Robert R. Doering, Senior Fellow and Research Strategy Manager, Texas Instruments

Questions submitted by Chairman Bart Gordon

Q1. Is there a need to expand the availability of nanotechnology user facilities that would be relevant to industry's needs? If so, would the NSF Industry-University Research Centers model be a viable mechanism for expanding the number and diversity of nanotechnology user facilities? Under such a model, federal funding would support the initial start-up costs, administration, and staffing needs of the user facility, while industry would provide the bulk of funding through user fees for use of the facilities.

A1. In terms of infrastructure, many U.S. universities and some federal labs have excellent facilities for doing *micro*-electronics research, but nanoelectronics may require more specialized tools for fabricating and characterizing these structures to move beyond the initial single device lab demonstrations. SIA estimates this will require an order of magnitude above current National Nanotechnology Infrastructure Network (NNIN) investments, which are roughly $15M. We are pleased to see the revised bill includes an assessment of equipment/infrastructure needs in the areas of national importance.

The Industry-University Research Centers model may be instructive, but given the modest investment of NSF through this program, it would not be adequate for addressing the needs in nanoelectronics, particularly once the technology demonstration phase begins. With its investment in equipment and facilities at a range of universities, expanding the infrastructure created by NNIN may be a more appropriate model for the semiconductor industry. The NSECs also provide an excellent resource for industry to work collaboratively with universities, such as through the co-funding of proposals that NSF has undertaken with the Nanoelectronics Research Initiative (NRI).

In addition, the modeling capabilities NSF has funded through the Network for Computational Nanotechnology (NCN, Purdue University) have been extremely helpful for industry in experimental/test and theoretical simulations of various options under NRI. NCN is an excellent model of a university-based facility which is easily accessible and frequently used by industry.

Q2. To what extent are nanotechnology businesses engaged in educational outreach activities with high school students or post-secondary students? Do your companies sponsor activities at informal science institutions?

A2. At Texas Instruments, education is the highest priority for corporate philanthropy. Each year, TI makes financial contributions totaling millions of dollars in grants and other gifts to schools, colleges and educational programs. TI supports a number of programs focused on fostering student interest and achievement in science, technology, engineering and math.

TI and Southern Methodist University co-developed the Infinity Project, which uses MP3 players and cell phones to teach engineering and science concepts to high school students in 275 schools in 37 states.

Since the early 1990s, TI engineers have been helping high school students in the Texas BEST (Boosting Engineering, Science and Technology) competition that challenges students to build remote-controlled robots, attracting nearly 700 middle and high schools and more than 8,000 students across several states each fall.

At the university level, TI was a leader in establishing and funding the Texas Engineering and Technical Consortium (TETC). TETC supports recruitment and retention of electrical engineering and computer science majors at 34 universities in Texas. From 2001 to 2006, electrical engineering graduates at TETC funded institutions increased by 49 percent compared to a 10 percent increase by other state and national institutions. Computer science graduates have declined across the U.S. The number of graduates at TETC institutions have only declined by six percent compared to the national decline of 24 percent.

For details on TI educational activities, visit: *http://www.ti.com/corp/docs/company/citizen/factsheets/cte.shtml*

Questions submitted by Representative Ralph M. Hall

Q1. What are the successes of the NNI over the past five years? Does the draft before us preserve the elements that led to these successes? What parts of the NNI have failed? Are there elements the Committee should consider terminating?

A1. Over the past five years, the National Nanotechnology Coordinating Office (NNCO) has advanced U.S. nanotechnology research by providing a focal point for federal activities in nanotechnology, leading to the development of strategic plans that identified program component areas, and brought together key stakeholders for workshops on major nanotechnology topics.

The NRI is certainly a model partnership under the NNI, leveraging nanotechnology-focused federal investments such as the NSF's activities at NSECs and the NNIN, and NIST's expertise in metrology at the nanoscale.

To quote the most recent NNI strategic plan profile of the NRI, "these government-industry-academic partnerships blend the discovery mission of NSF, the technology innovation mission of NIST, the practical perspective of industry, and the technical expertise of U.S. universities to address a nanotechnology research and development priority. It is one example of the creative methods the NNI uses to accelerate research that contributes to the Nation's economic competitiveness."

A major shortcoming of the NNI currently is that it does not have a mechanism to prioritize interagency activity and resources around nanotechnology research that addresses the most critical challenges facing our country. The bill's identification of areas of national importance is essential to ensuring that this occurs.

Further, the NNI would benefit from clearer metrics and time frames for both near- and long-term objectives, including plans for technology transition with industry and the states. The bill's call for this to be addressed in the strategic plan allows better measurement of progress towards NNI goals. The explicit funding mechanism for the NNCO and authorization of travel expenditures are also positive proposals for improving the way the NNI is planned and implemented.

Q2. How would you address the concerns of those who might perceive Congress as picking winners and losers by specifically naming areas of national importance in the legislation?

A2. It is important that the bill recognizes that projects in these areas will be selected on a *competitive and merit* basis. It is appropriate for the legislation to identify some examples of areas of national importance, and call for the Advisory Panel to identify additional areas. This will allow NNI to prioritize resources around national challenges that would benefit from breakthroughs in nanotechnology and where the Federal Government has a unique role in funding exploratory research.

Q3. In your testimony you advocate for the inclusion of security as a major area of national importance. Currently, the Department of Defense accounts for more spending under NNI than any other agency. However, the Department of Homeland Security invests just one million dollars, less than all agencies except the Department of Transportation. Are there specific areas where nanotechnology can uniquely benefit homeland security that are being ignored currently?

A3. Security is an important national challenge that will benefit from nanotechnology research. Even if not addressed in the legislation, this topic should certainly be prominent in the interagency context. For example, nanoelectronics benefits national security in very many ways, including even smarter weapons, better and quicker situational awareness, lightweight and low-power communication devices, and a broad range of small sensors such as single-chip chemical and biological detection and analysis platforms. Nanomaterials will allow lighter and stronger vehicles, equipment, and armor for military and first responders.

As noted, the Department of Defense invests more in nanotechnology research than any other agency in NNI, and much of this research will have security applications. DHS should leverage promising nanotechnology research through NNI by providing its expertise and agency funding, where appropriate, for specific applications related to its mission.

Q4. What difference can you identify between the Nanoelectronics Research Initiative (NRI) and the partnerships described in Section 5 of the draft legislation? In your opinion, what effect will these differences have on the success of further partnerships?

A4. The NRI in its current form is a model of the partnerships envisioned in Section 5, involving an industry consortium, universities, and two federal agencies. The NRI also leverages state investment, which was not an element in the initial draft of Section 5, and we are pleased to see this aspect recognized in the revised text.

The major difference between the NRI and the partnerships envisioned in Section 5 is that currently under NNI, there is no designation as an area of national importance and such partnerships are not explicitly recognized. The legislation as drafted will encourage such beneficial partnerships.

As NRI moves forward, its model may evolve to include technology demonstration projects of promising concepts. This was not envisioned for partnerships in the original Section 5, but we are pleased to see the bill as introduced recognizes this need.

Questions submitted by Representative Daniel Lipinski

Q1. As we know, many companies who have taken advantage of the benefits of nanotechnology choose not to advertise this facet in their products, for fear of public backlash. I understand their concerns as I do not believe the general public has a solid understanding of nanotechnology. Does the legislation do enough to enhance public awareness and education in the field of nanotechnology? Is additional international cooperation needed to assist the United States in educating our citizens? Can you give us some examples of what other countries are doing to inform and educate their people?

A1. Certainly improved public awareness of the benefits of nanotechnology and research around EHS issues will assist consumers in making informed decisions and reducing fears around nanotechnology.

ESH issues are important, but should not eclipse the vast potential benefits of nanotechnology. The semiconductor industry is committed to ensuring that its leadership in ESH continues as semiconductor technology advances.

To help meet the ESH challenges of the industry, the Semiconductor Research Corporation and SEMATECH, two industry consortia, sponsor the SRC/SEMATECH Engineering Research Center for Environmentally Benign Semiconductor Manufacturing, headquartered at the University of Arizona, and including researchers at 10 other leading universities.

The industry has an International Technology Roadmap for Semiconductors (ITRS) that is developed by over 1000 scientists and engineers worldwide. The roadmap includes an extensive section of ESH that provides direction to research centers, suppliers, and chip makers to focus on the both short-term (2005–2013) and long-term (2014–2020) challenges in chemical assessment and reduction, energy and water conservation, and sustainability and product stewardship. Specifically there is recognition of how the industry's ESH controls should be studied and adjusted as needed for nanomaterials.

From an education standpoint, nanotechnology provides an excellent opportunity to capture young imaginations to science—a nanometer is so small it could fit 50,000 times on the width of a typical human hair. The bill's education provisions, particularly the Nanotechnology Education Partnerships at the NSF, provide appropriate mechanisms to generate teacher and student enthusiasm and undergraduate interest in this area.

SIA has been involved in the International Nanotechnology Conference on Communications and Coordination, which brings together industry, academia, and government officials working in nanotechnology. In addition to research topics, programs have included discussions on various approaches to societal and educational dimensions of nanotechnology.

Q2. Nanoelectronics is an area within the field of nanotechnology that is certainly important, and I am curious to hear a little more about its current status. Could you give me a better sense of the work being conducted in this specific area, and what has resulted thus far from this research? Approximately how much funding is currently devoted to nanoelectronics? And is this funding adequate for what is needed to tackle the challenges of nanoelectronics and the work needed to smooth the transfer of the research into commercial products?

A2. Nanoelectronics research is focused on finding the new "switch" to replace today's transistor. The new switch must be extremely reliable, fast, low power, functionally dense, and capable of being manufactured in commercial volumes at low cost. There are a number of candidates for the new nanoelectronics switch, including devices based on spin or other quantum state variables rather than classical bulk electric charge. The NRI has identified several promising new phenomena that have potential to become advanced switches, such as pseudospintronics, ballistic anisotropic magneto-resistance, spin waves, molecular conformational changes, electron wave interference, nanomagnet interactions, and excitons in both molecules and carbon nanotubes and graphene. In particular, there is a large amount of research

going into graphene, which is showing great promise as a new material to support a number of new device technologies.

However, despite this long list of promising initial concepts, it should be emphasized that we have a long way to go. Our understanding of many of these new phenomena is in its infancy, and we will undoubtedly find many challenges and showstoppers which will limit the ultimate potential of most of the candidates—this is the nature of such far-out research. It also underlines the urgency for investing heavily now in many different areas.

Commercialization of devices based on these phenomena into a new class of integrated circuits may very well require an entirely new nanomanufacturing paradigm. Technology demonstration projects, as identified in the revised bill, will be required to advance to the next phase and determine the viability of the various technologies.

Current direct NRI funding from all sources (federal, industry, and State) totals about $25M annually, of which NIST funds about $3M per year, and NSF funds $2M.

However, an aggregate figure for all federal agency investments in nanoelectronics is currently extremely difficult to obtain—programs are disaggregated across agencies, and often not reported at such a detailed level. There are a number of activities relevant to nanoelectronics outside of the formal NRI partnerships with NSF and NIST. For example, the Department of Defense, largely through DARPA, is a major investor in nanoelectronics research. The Department of Energy laboratories conduct activities and have capabilities relevant to nanoelectronics as well.

The 2009 National Science Foundation budget request was the first time the agency included a $20M initiative for research addressing “Science and Engineering Beyond Moore’s Law,” thus establishing a centralized figure for the agency’s activity on this topic.

The revision to Section 5 to track investments in the areas of national interest, at the same level of detail as is currently done for the Program Component Areas will be extremely valuable to have federal investment for these areas available in a central location and to monitor trends.

Q3. States obviously play an important role in commercialization and translation of promising research into innovation, which in turn enhances regional economic growth. Does the legislation sufficiently address the role of the states in nanotechnology?

A3. TI and SIA agree that State governments can play an important role. Section 4 of the draft legislation highlights technology transfer and explicitly identifies the importance of State leverage through research, development, and technology transfer initiatives. We were pleased that the bill as introduced revised Section 5 to recognize that projects in areas of national importance should leverage State funding where possible.

For example, Texas created a $200M Emerging Technology Fund to invest in public-private endeavors around emerging scientific or technology fields tied to competitiveness; match federal and other sponsored investment in science; and attract and enhance research talent superiority in Texas. Several other states have similar mechanisms. Of course, State governments are also critical in supporting public research universities from an overall budget perspective.

States have provided leveraged funding to NRI worth at least $15M annually in funding, equipment, and faculty endowments. In addition, several states have invested in expansion or construction of new buildings related to nanotechnology. The City of South Bend, with the new Midwest Academy of Nanoelectronics and Architectures (MANA) NRI center, will open an “Innovation Park” adjacent to the campus designed to foster commercialization.

Questions submitted by Representative Michael T. McCaul

Q1. The NRI SWAN center based at the University of Texas Austin includes significant resources from the State of Texas, the University of Texas System, and Texas industry. Specifically, how does this provide leverage to the federal investment in NRI research and benefit universities outside of the University of Texas System?

A1. While Texas and other states have provided resources to the four regional NRI centers, it is important to note that these regional centers are “virtual” and involve researchers from several universities outside these states. Collaborative research occurs on a national level at all 35 participating universities. In addition to UT–Aus-

tin, SWAN involves researchers at UT–Dallas, Texas A&M, Rice, Arizona State, Notre Dame, Maryland, NC State, and Univ. of Illinois–C.

The SWAN $30M in matching funds is focused on attracting and supporting top academic researchers in nanoelectronics. Specifically, this is a three-way match, with the State of Texas contributing $10M from the Emerging Technology Fund, the University of Texas System matching with $10M, and the remaining $10M contributed by Texas industry for endowed chairs, including $5M from TI. Like similar investments in other states, these funds are restricted to support faculty at public institutions in the state. However, such state investments indirectly benefit other universities participating in the various centers by enabling research capacity and infrastructure that otherwise would not be funded. The NRI's State and local investments leverage the federal and industry contributions to further advance nanoelectronics research.

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